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THE 1970 LABOR DAY WEEKEND FLOOD IN THE VICINITY OF UPPER TONTO CREEK, ARIZONA

U. S. FOREST SERVICE
SOUTHWESTERN REGION
JULY 1971

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ROCKY MOUNTAIN STATION

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ROCKY MOUNTAIN STATION

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SUMMARY FINDINGS AND HIGHLIGHTS

1. Unprecedented amounts of rainfall, possibly as high as 18 inches in localized areas, fell on Tonto Creek during the period September 4-6, 1971.

2. One- to 24-hour duration rainfall on the Tonto Creek Watershed as determined by this study, exceeds any on record for the State of Arizona.

3. The most outstanding characteristics of the storm over the Tonto Creek Watershed determined by this analysis, is the approximately 1-1/2 hour period of sustained high intensity rainfall which fell during the afternoon of September 5.

4. The 100-year storm was equaled and may have been exceeded by as much as two times on Tonto Creek.

5. The Labor Day storm established new peak flow records for central Arizona. Tonto Creek's peak discharge was at least twice the 50-year flood which is no greater by comparison than several other widely separated streams in central Arizona.

6. This most recent flood is the most destructive for Tonto Creek but geologically speaking it is a natural phenomenon of unpredictable occurrence.

7. Twenty subwatersheds within and adjacent to Tonto Creek were field sampled and analyzed.

8. Rainfall from as low as 4 inches to as high as 18 inches is estimated to have fallen within a comparatively small area due to topographic influences.

9. Variations in rainfall caused more of the variation in peak flow than did any other factor.

10. Computed runoff varied from less than one area inch to over twelve area inches.

11. Hydrographs of reconstructed runoff indicate that smaller tributary Watersheds were sustained at high levels of flow for periods of over one hour.

12. Even though unprecedented amounts of rainfall fell in the storm of September 5, the Tonto Creek Watershed could have withstood these amounts without damage if the rainfall had been evenly distributed in time.

13. Very little on-slope damage has been observed while channel damage is severe and widespread.

14. Runoff was abnormally high on top of the Mogollon Rim, but practically no on-site or channel damage occurred.

15. Channel damage on the face of the Rim was the worst in centuries while slope damage was negligible except for isolated mass movement.

16. Stream channel beds composed of rock and soil accumulating over a period of centuries literally slid down the face of the Rim.

17. Evidence of on-slope runoff below the Rim was typical of that frequently found following summer thunderstorms.

18. Channel flows originating below the Rim were relatively non-destructive compared with major drainages which began above the Rim or on its face.

19. Stream channel damage was severe on more than eight miles of major channels in the Tonto Creek. Dick Williams Creek, with a watershed of only 558 acres, was probably the most severely damaged stream channel in the state.

20. The pre-flood channel materials in Dick Williams Creek are gone from most of its length and a 100 foot wide gutted trench now exists.

21. Boulder deposits in severely damaged channels are 10 to 30 feet deep and up to one-quarter mile long.

22. Uprooted trees increase the destructiveness of the flood flow more than any other factor. Over 100 acres of standing trees were uprooted and swept away.

23. The storm characteristic that contributed most to the damaging aspects of the flood was the long duration during which intense rainfall fell. This period of about 1-1/2 hours provided a continuing flow of water to transport dislodged masses of rock, soil, and dismembered trees.

24. Three major wildfires have burned 4,358 acres or about 32 percent of the Tonto Creek Watershed within the past ten years. These burned areas were seeded by aircraft and revegetation was highly successful.

25. All evidence points to more storm runoff and higher peak flows from burned areas in contrast to their preburn condition. This increase is attributed to decreased ground cover and a resulting decrease in infiltration capacity. Due to shallow rocky soils on part of the burned areas and slow infiltration rates on the remaining burned areas, the relative values of tree versus grass cover in providing soil water storage capacity was not a significant factor in the Labor Day flood on the Tonto Creek Watershed.

26. Attributing more runoff to burned as contrasted to unburned areas in general is supported by well documented research.

27. Approximately five inches of storm rainfall were stored in the soils of the Tonto Creek Watershed. On 34 percent of the watershed, storage capacity was not fully utilized due to the inherent low infiltration capacity of the soils and the high rainfall intensity.

28. Within the Tonto Creek Watershed, peak flows from small tributary watershed may have been increased by as much as 26 percent due to burned conditions; but the total effect on the peak in Tonto Creek at Kohl's Ranch was an increase of only 3 percent. This small increase in runoff from the burned areas is attributed to successful revegetation and the widespread distribution of the burns.

29. Channel damage was severe on both burned and unburned watersheds.

30. Channel damage below debris flows was greater than above.

31. Three large debris flows on Upper Dick Williams Creek deposited approximately 14,000 cubic yards of material in the stream channel causing severe damage downstream. Adjacent and similar burned watersheds show comparatively minor channel damage although their peak flows were very high being over 4,000 csm (cubic feet per second per square mile).

32. All debris flows observed were within burned areas but other factors rule out any definitive conclusion that the debris flows were fire caused.

33. As a result of natural scouring during the flood and a $400,000 emergency channel restoration program by the Forest Service on National Forest lands complimented by a similar program by the Corps of Engineers on private lands, the major stream channels in the Tonto Creek Watershed have more capacity to carry flood waters today than they had prior to September 5, 1970.

CONCLUSIONS

1. The principal causes of the destructiveness of Labor Day Weekend flood on Tonto Creek were:

   a. The natural geomorphic characteristics of the rocky and abruptly rising Mogollon Rim bordering the bowl shaped watershed.

   b. The unprecedented magnitude of the record breaking storm-the worst in centuries.

   c. The vulnerability of large numbers of unexpectant recreationists and improvements lying upon the flood plain.

2. Burns from past wildfires in the Tonto Creek Watershed cannot be credited with appreciably affecting the magnitude of the Labor Day Weekend Flood in the vicinity of Kohl's Ranch.

3. Tonto Creek could withstand a storm of similar magnitude to the Labor Day Storm today better than before the flood due to channel clearing during the flood and cleanup operations following the flood.

4. The effects of the Labor Day Flood will be evident for many years as the stream channels aggrade or degrade to natural levels.

5. A storm of equal or greater magnitude to the Labor Day Storm could still occur at any time.

RECOMMENDATIONS

1. No effort should be made to design National Forest facilities on the basis of the extreme climatic event associated with the September 1970 flood. Management should continue to be based upon existing peak flow design criteria which considers probabilities, risks, and costs.

2. All existing overnight campgrounds and other public use facilities occupying flood plains in the Southwestern Region should be surveyed to determine the flood crest elevation for a range of flood frequencies and action be taken to insure that the public is informed where there is a potential danger.

3. Final locations for all proposed developments to be installed on National Forest flood plains in the Southwestern Region should be selected in relation to the elevation of the appropriate design flood crest.

4. A flood warning and evacuation plan should be prepared for all high risk areas as determined by recommendations No. 2 and 3 including provisions for rapid relay of flood warnings issued by local offices of the U. S. Weather Service.

5. Where consistent with environmental protection requirements, selective clearing of unneeded obstructions and debris from stream channels above high use and development facilities on flood plains should receive special emphasis in the Southwestern Region Multiple Use Guide. Although the major source of debris in the Tonto Creek flood was from live standing trees uprooted due to the extreme magnitude of the storm, it is well established that intermediate class floods can be more destructive if debris is available and channel obstructions are present.

6. The September 1970 flood should be used as the basis of an I&E program for creating an awareness in remote area recreationists of flood hazards in the arid Southwest, how to provide for their own safety, and illustrating one of nature's ways in shaping the earth's surface.

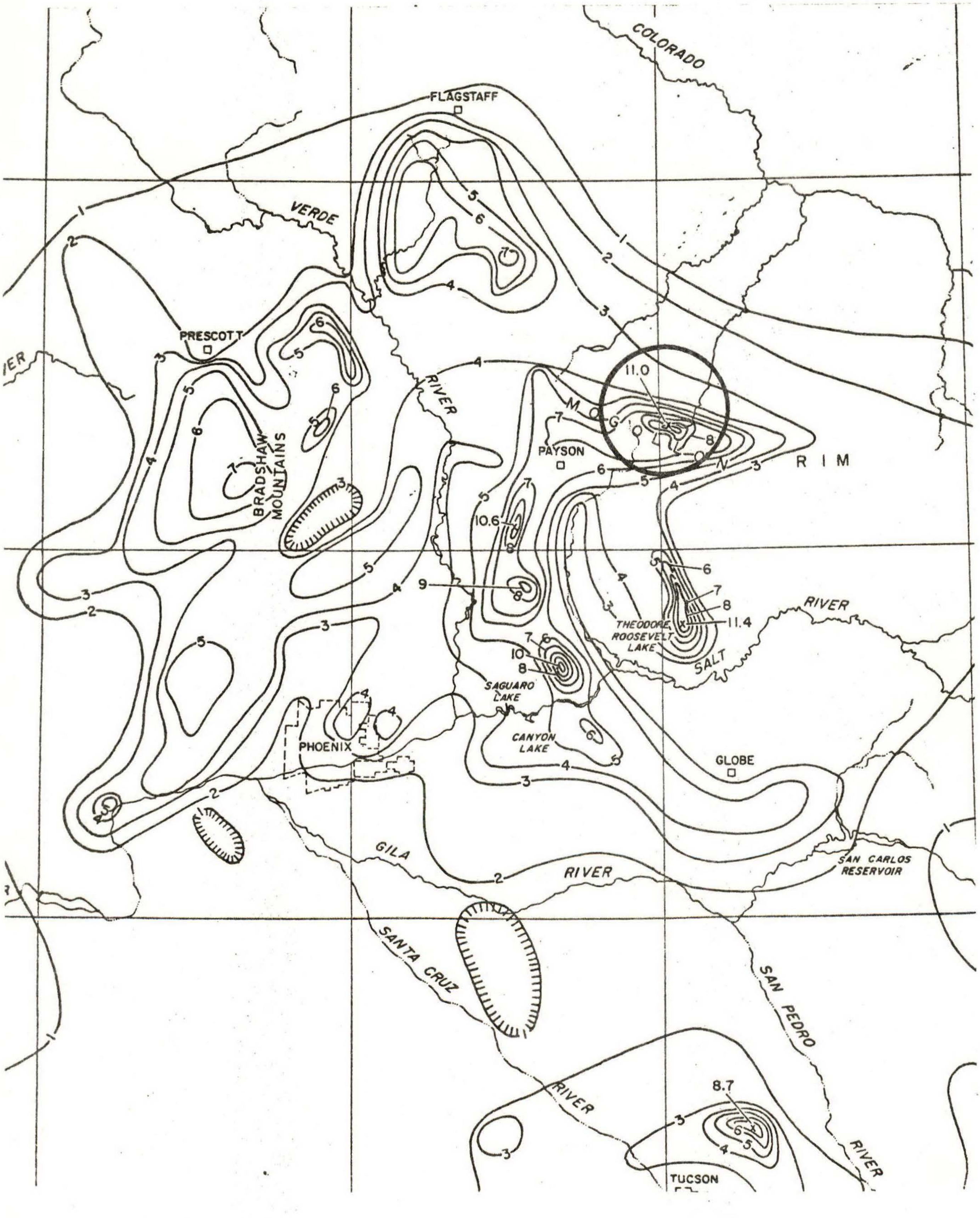


Figure - 1 Vicinity map showing study area and isohyets for September 4-6, 1970 rainfall. (From Arizona State Land Dept., Water-Resources Rpt. No. 44)

INTRODUCTION

Unprecedented rainfall on September 4, 5, and 6, 1970, caused widespread flooding throughout central and northeastern Arizona, southeastern Utah, and southwestern Colorado. Five of the damaged counties in Arizona and 14 in Colorado were declared national disaster areas qualifying for Federal assistance through the Office of Emergency Planning.

In Arizona, 23 lives were lost and property valued in excess of six million dollars was destroyed by the floods.

The popular summer recreation areas near Kohl's Ranch on Tonto Creek and nearby Christopher Creek, Arizona were severely damaged and accounted for more lives lost than any other area where the storm occurred.

The headwaters of both Tonto and Christopher Creeks lie within the Tonto National Forest. Public land management programs administered by the Forest Service provide for recreation use and enjoyment of these popular forested mountain lands. The Forest Service objective in initiating this study is to quantify and analyze the hydrometeorlogical events that took place on September 4-6. With this information National Forest land managers will be able to place existing land management programs in better perspective and to evaluate future land management decisions knowledgeably in terms of their interrelationship to potential catastrophic floods.

THE STUDY AREA

Although extremely heavy damage occurred over a five-county area of central and northeastern Arizona on September 4-6, 1970, this study was confined to the Tonto Creek Watershed above State Highway 160 at Kohl's Ranch which is approximately 20 miles east of the town of Payson, Arizona. Limiting the study area to this 13,700 acre watershed enabled a more thorough investigation and analysis to be made in one of the areas of more severe damage. The watershed includes great topographic variety. From a low elevation of 5320 feet, it rises abruptly to 7867 feet on top of the Mogollon Rim, a prominant fault-created escarpment transversing central Arizona. A wide range of soil types are present. The predominant natural vegetation on the watershed is ponderosa pine with the exception of two areas where wildfires in 1961 and 1968 burned a total of 4358 acres now revegetated to grass.

THE STUDY TEAM

A Forest Service multi-disciplinary evaluation team surveyed the watershed in early October while high water marks and other flood water evidence was fresh. One Forest Service Research scientist participated in the field survey and provided gaged data from study watersheds in the same hydroclimatic zone. Emphasis was given to incorporating data on soils, geology, hydrology and forest and range management.

The analysis of storm events in remote areas is seldom facilitated by gaged climatic data. This typical situation is true for Upper Tonto Creek. Only one rain gage recorded the rain that fell within this watershed. For this reason, it was necessary to reconstruct the storm and the events which followed. This analysis was prepared from information obtained from witnesses who observed the storm, field measurements of high water marks and other physical and biological characteristics and evidence within the watershed, the transposition of recorded data from gaged sites adjacent and nearby, and aerial reconnaissance and photographic flights made after the flood. Individually these fragments of information did not offer sufficient enlightment; however, when their interrelationship was established through analysis the events leading to the flood of September 5 are better understood.

THE TONTO CREEK FLOOD - AFTERNOON OF SEPTEMBER 5, 1970

Intermittant rainfall began along the Mogollon Rim during the afternoon and evening of September 4. At approximately midnight a steady heavy rain commenced which continued in most areas for another 24 hours or longer. By noon on Saturday the 5th, two or more inches of rain had fallen across most of the rim country and in some localities the amount was as much as six inches. The Phoenix Office of the National Weather Service issued the following warning at 2 P.M. on the 5th for Maricopa, Yavapai, Coconino, and Gila Counties, "continued heavy rains over these counties have caused extensive runoff into streams and washes. More heavy rains are forecast for this evening and further rises may take place tonight. Many dips in unbridged river crossings have become very dangerous due to high water and some have become inpassable."

Water in Tonto Creek and Christopher Creek was running high by 2 P.M. and some campers on Christopher Creek had already been stranded. Forest Service patrolmen ordered barricades and warning devices and campers were being contacted and warned of the impending flood waters. By 3:30 P.M. flood waters were rising rapidly and by 4:30 P.M. they had spread onto adjacent flats along Tonto Creek and over the top of the Tonto Creek bridge on State 260. During this period, a number of tragic accidents were taking place. A foreign mini-bus with its occupant family was

hit by a wall of water and swept into the flood waters from the Horton Creek Bridge, along with a would-be rescuer. And further downstream, observers saw parts of two summer homes, two cars, and eight house trailers float by.

Eyewitness accounts indicate that one of the more terrifying aspects of the flood was the noise created by the rolling, bouncing, and colliding of boulders, some as large as a small car. Uprooted trees battered bridge abutments and decks adding to the frightening clamor.

The flood waters receded almost as quickly as they had risen. The water level was down 4 to 5 feet by 5:30 P.M. and was no longer going over the Tonto Creek Bridge. During this short cataclysmic period, 14 lives had been lost along Upper Tonto Creek near Kohl's Ranch, and one in the Upper Christopher Creek area. It will require approximately 3 million dollars to repair damages to National Forest improvements alone on the Tonto National Forest.

Emergency operations to protect the local and traveling public were implemented immediately. Special Forest Service flood damage assessment teams determined both the short term and long term restoration needs. Project Ringtail, a $400,000 stream channel restoration operation, began on February 16, 1971, to restore 35% of the most critical damaged channels in the rim area before the spring runoff could begin. This first priority work on National Forest lands was designed to provide protection for life and property along Tonto and Christopher Creeks in the event that subsequent floods occurred. It was coordinated with work being done concurrently on private lands by the Corps of Engineers. Destruction and damage to National Forest roads and trails was so severe that a period of three years will be required to restore them to acceptable condition.

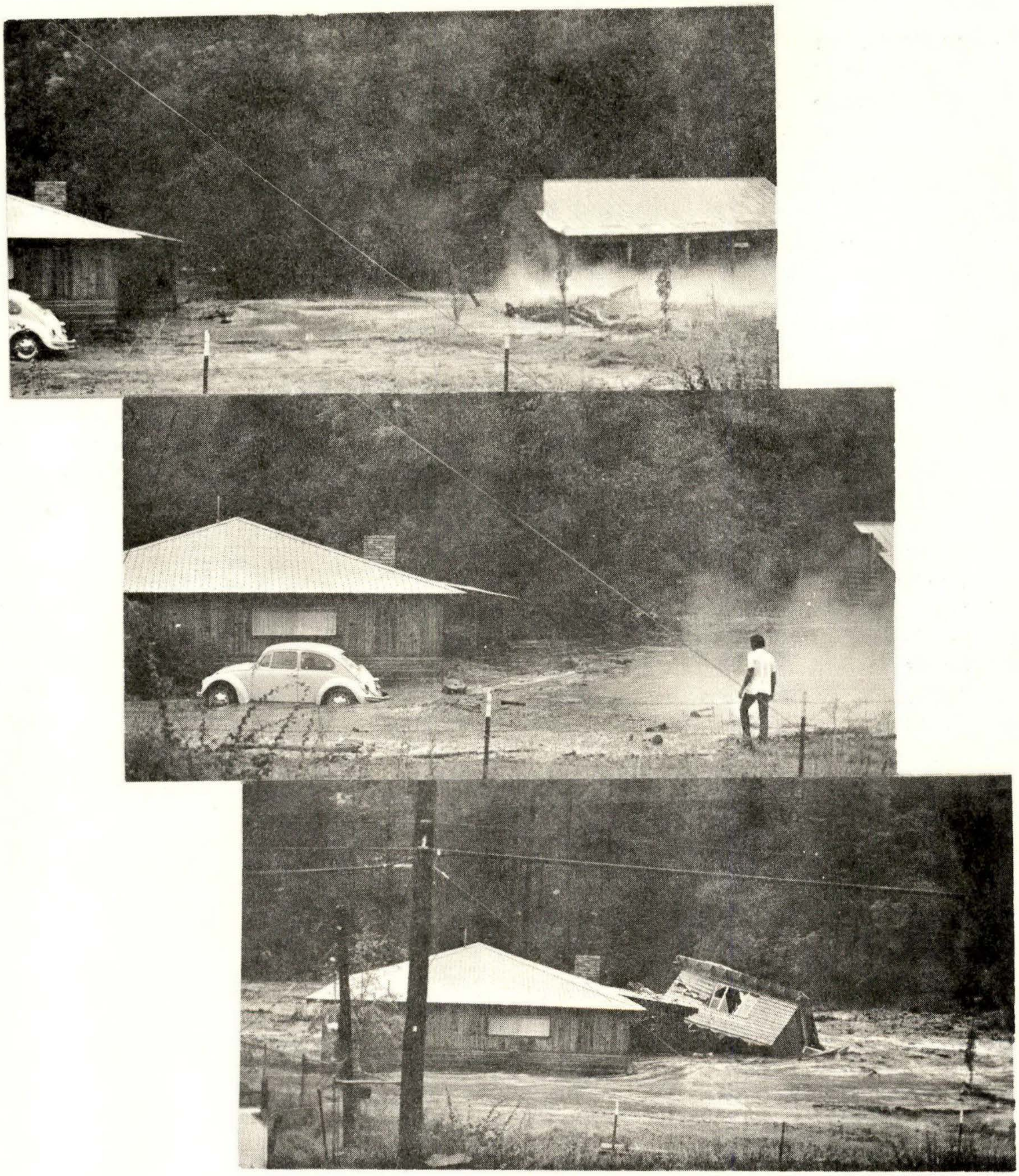


Photo 1 - Sequence of photographs showing a dwelling being swept away by Tonto Creek flood waters on September 5, 1970.

Photo 2 - Flood flow in Tonto Creek below Kohl's Ranch. Observers saw parts of two summer homes, two cars and eight house trailers float by in the vicinity of where these photographs were taken.

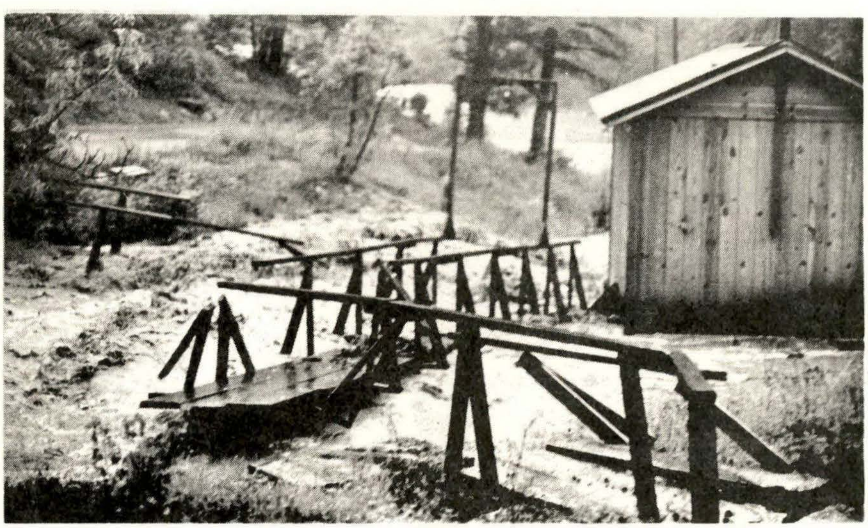


Photo 3 - Over 100 acres of live trees were torn out by the flood waters. Eyewitness accounts indicate that one of the more terrifying aspects of the flood was the noise created by the rolling, bouncing, and colliding boulders. Note men in upper and lower photographs at point of markers.

THE EVENTS OF SEPTEMBER 4 - 6 IN REGIONAL PERSPECTIVE

RAINFALL

1. *Unprecedented amounts of rainfall, possibly as high as 18 inches in localized areas, fell on Tonto Creek during the period September 4-6, 1971.*

The storm that brought nearly 12 inches of measured rainfall within 24 hours to the Sierra Ancha Mountains of Central Arizona was caused by a rare combination of cold air colliding with warm wet tropical air. The cold air from the Pacific Northwest moved across the state in a southeasterly direction. The tropical air was pushed into Arizona from the south by hurricane Norma which was lying over the Pacific Ocean south of Baja, California. The phenomenon of cold dry air, and warm moist air meeting and causing rainfall over this area is not unusual. Each year the pattern is potentially possible during late August or early September. Large storms occurred over the same area in the late summers of 1951 and 1966, but never before during recorded history were the dimensions of the two bodies of air and triggering mechanisms great enough and in the right combination to produce a storm equal to the Labor Day Storm of 1970.

Twenty-four hour rainfall at several official Weather Service gaging stations exceeded previous observational day records. Those of most interest in relation to Tonto Creek are listed in table 1.

Table 1 - New observational day rainfall records

Station	Amount	Date Sept.	Records Began	Previous Record Amount	Previous Record Date
	inches			inches	
Payson 12NNE	4.29	5th	Mar. 1950	3.53	7-31-67
Payson R.S.	6.20	5th	Jan. 1892	4.37	10-29-59
Payson	5.36	5th	Aug. 1948	3.74	10-29-59
Tonto Creek Fish Hatchery	5.36	6th	June 1944	4.30	1-26-57

In the Kohl's Ranch area, unofficial rainfall measurements for the storm period ranged from about 6 to 8 inches. Rainfall amounts from official and unofficial observations near Tonto Creek are tabulated in table 2. The Geological Survey has shown (fig. 1) that storm rainfall was as high as 11 inches in the vicinity of Tonto Creek.

Table 2 - Storm rainfall in the vicinity of Tonto Creek for September 4-6, 1970.

Location	Elevation	September 4-6 Rainfall in Inches 1/			
		4	5	6	Storm Total
Payson 12 NNE	5,500	0.38	4.29	0.21	4.88
Payson Ranger Station	4,848	0.23	6.20		6.43
Payson	4,913	0.25	5.36	1.09	6.45
Tonto Creek Fish Hatchery	6,280	0.25	1.25	5.63	7.13
Baker Butte	8,076				6.42
Lake No. 1	7,600		7.80		
Canyon Point	7,600		7.08		
Kohl's Ranch	5,350*				7.30
Kohl's Ranch	6,000		6.20		
Diamond Point	6,318		6.08		
Christopher Creek	6,000*		8.60		11.00
Gordon Canyon Ranch	6,300		10.00		
Colcord Maintenance Yard	6,400				7.80
Indian Gardens	5,450				7.98
Webber Creek B.S.A.	5,400				6.98
Woods Canyon Lake	7,650				8.00

1/ No rainfall was recorded at any of the listed stations on September 3 or 7.

* Approximate elevation.

Table 3 - Comparative point rainfall.

Station	Duration: Minutes 5	15	30	Hours 1	24	Storm Total
			Long Term Maximum Recorded			
Flagstaff	.41	.84	1.18	2.00	3.59	
Prescott	.40	.84	1.34	2.02	3.08	
Winslow	.51	.92	.96	1.08	2.12	
			September 4-6, Storm			
Workman Cr. C.S.	.46	.50	.97	1.41	8.40	11.35
Workman Cr. S.F.	.17	.52	.99	1.66	10.52	11.75
Pocket Creek	.26	.79	1.49	1.57	5.87	7.17
3-Bar D-2	.25	.63	.83	1.19	7.44	8.04
Sycamore Cr. W.F.	1.50	-	-	-	-	7.75
Payson	-	-	-	1.1	5.36	6.45
Tonto Creek - Kohl's Ranch	(.3)1/	(.8)	(1.6)	(3.2)	(7.0)	7.6
Tonto Creek - Rim	(.6)	(1.7)	(3.4)	(6.7)	(14.7)	16.0
			Weather Service 100-Year Storm			
Kohl's Ranch Area	.8	1.5	2.1	2.8	6.5	

1/ Estimated values read from constructed dimensionless mass curve. Amounts for less than 1 hour should not be construed as short interval bursts of rainfall, but rather as readings from the constant slope of the mass curve during the steepest 1 hour period.

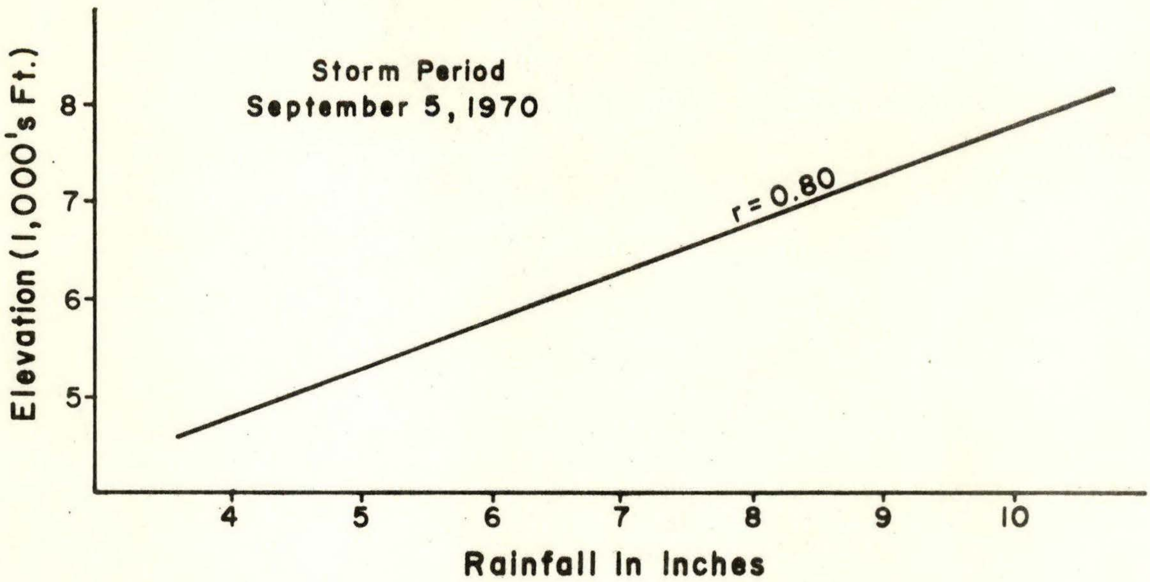
Table 4 - Rainfall Frequency 1/

Duration	Kohl's Ranch Area			Mogollon Rim - Headwaters Tonto Creek		
	Observed or Reconstructed 7.6 In. Storm	100 Year Storm (TP 40 & 49)	Ratio of Observed To 100 Year	Observed or Reconstructed 16 In. Storm	100 2/ Year Storm (TP 40 & 49)	Ratio of Observed To 100 Year
5 Min.	0.3	0.8	0.38	0.6	0.8	0.70
10 Min.	0.5	1.2	0.42	1.1	1.2	0.95
15 Min.	0.8	1.5	0.53	1.7	1.5	1.14
30 Min.	1.6	2.1	0.76	3.4	2.1	1.63
1 Hr.	3.2	2.8	1.14	6.7	2.8	2.40
2 Hr.	4.0	3.7	1.08	8.3	3.7	2.25
6 Hr.	5.0	4.5	1.11	10.6	5.0	2.12
24 Hr.	7.0*	6.5	1.08	14.7	7.0	2.10
2 Day	7.2*	7.0	1.03	15.2	7.0	2.17
4 Day	7.6*	8.0	0.95	16.0	8.0	2.00

*Observed

1/ All 100-year storm values obtained from U.S. Weather Bureau Tech. papers Nos. 40 & 49 and Ispopluvial Maps for Arizona.

2/ Probable maximum 6-hour rainfall over 10 square miles (TP 40) is 20 inches. Although 100-year amounts are listed as published, their applicability to the Rim area is questionable due to lack of gaging stations and observations.



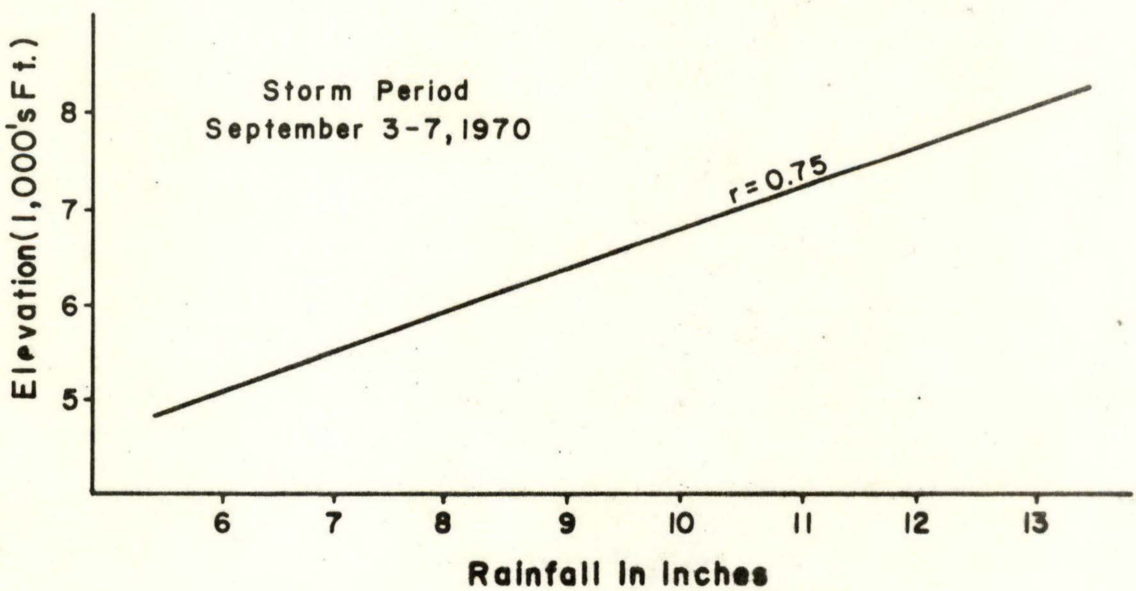


Fig. 2. Rainfall in relation to elevation for Tonto Creek Watershed.

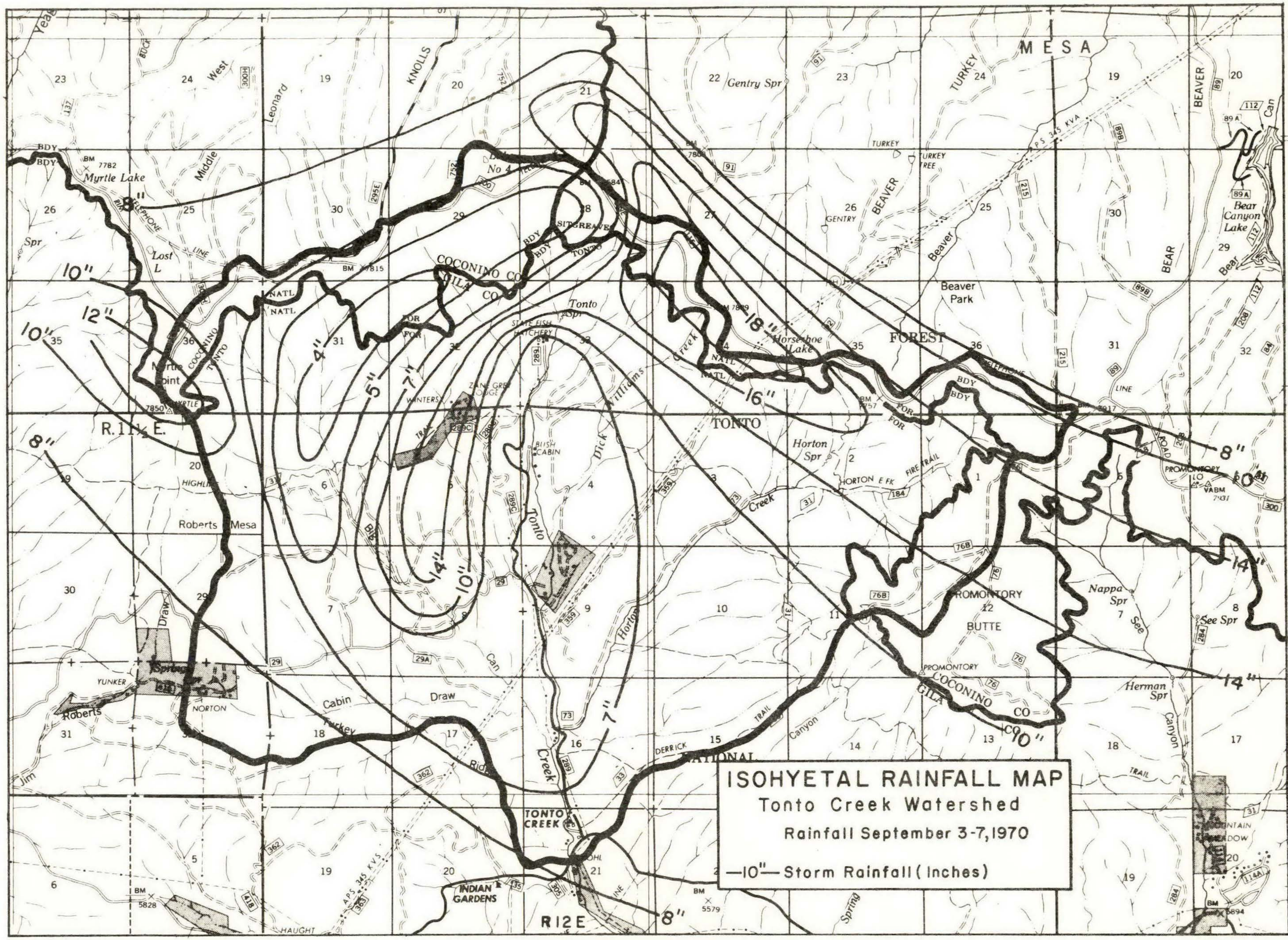

ISOHYETAL RAINFALL MAP
Tonto Creek Watershed
Rainfall September 3-7,1970
—10"— Storm Rainfall (Inches)
MESA
COCONINO CO
GILA CO
Tonto Spr
Horseshoe Lake
FOREST
TONTO
Horton Spr
PROMONTORY
BUTTE
Roberts Mesa
Myrtle Lake
Beaver Park
Bear Canyon Lake
Nappa Spr
See Spr
Herman Spr
TONTO CREEK
INDIAN GARDENS
R.11½ E.
R12E
T.11 N.
25'
20'
4"
5"
7"
8"
10"
12"
14"
16"
18"

Figure 3

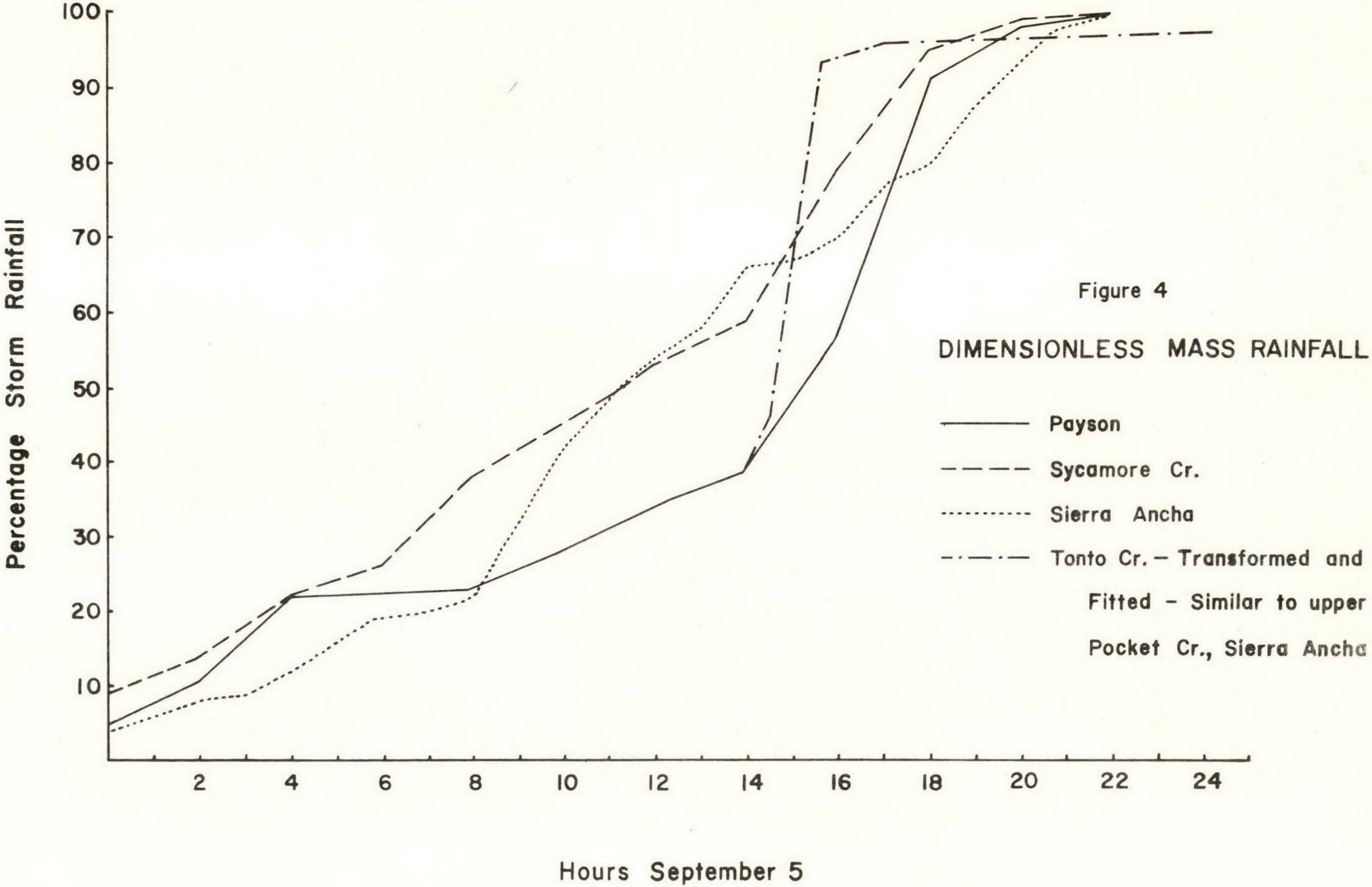


Figure 4

DIMENSIONLESS MASS RAINFALL

An analysis of rainfall within the Tonto Creek Watershed study area indicates that rainfall amounts were highly variable and probably ranged from as low as 4 inches to as high as 18 inches. This great variation is attributed to the large and abrupt changes in elevation associated with the Mogollon Rim and the orographic influence of such prominent topographic features as Myrtle and Promontory Points. A good correlation was found between elevation and precipitation for this storm throughout Central Arizona. Figure 2 illustrates the relationship between rainfall and elevation applicable to the Tonto Creek Area. On the basis of elevation alone, it is probable that higher elevations along the Rim received as much as 13 inches of rainfall during the storm and as much as 10.5 inches on September 5. Peak flow determinations are the basis for the higher projected rainfall amount of 18 inches. The isohyetal storm rainfall map for Tonto Creek is shown in figure 3. This map of rainfall distribution was developed using all available evidence of rainfall amounts.

2. *One- to 24-hour duration rainfall on the Tonto Creek Watershed, as determined by this study, exceeds any on record for the State of Arizona.*

No recording rain gages were in operation on or near the study area to provide an accurate record of rainfall intensities. Periodic rainfall amounts were recorded at Payson and continuous recordings were available for analysis from Forest Service Research studies from several wide-spread areas. A dimensionless mass rainfall curve (percent accumulated rainfall plotted against time) was developed for the Tonto Creek Watershed using all available data. This analysis indicates that rainfall amounts for 1-hour and longer durations exceeds any on record for Arizona. Recorded point rainfall is summarized in table 3. Figure 4 illustrates four dimensionless mass rainfall curves. The Tonto Creek curve consists of a transformation using the general time distribution of the Payson curve and recorded data from Pocket Creek, near Sierra Ancha, which exhibited the highest prolonged intensity of any applicable records investigated.

3. *The most outstanding characteristic of the storm over the Tonto Creek Watershed determined by this analysis, is the approximately 1-1/2 hour period of sustained high intensity rainfall which fell during the afternoon of September 5.*

4. *The 100-year storm was equaled and may have been exceeded by as much as two times on Tonto Creek.*

The rainfall in the Kohl's Ranch area can be classified at least as a 100-year storm (table 4). This analysis was made by comparing Tonto Creek rainfall with 100-year storms listed in Weather Service publications for this area. Estimated amounts of rainfall for the Labor

Day storm along the Rim, range from a 100-year storm to twice the amounts predicted in the 100-year storm. The period in this storm estimated to have the least frequent occurrence is one hour. For example, over 6 inches of rainfall may have fallen in a one-hour period on top of the Rim above the Tonto Creek Fish Hatchery. This is an important aspect of the storm as will be discussed later in the report. Note however, that caution is used in classifying the frequency of occurrence for this remote area. Very little is known about historical precipitation along the Rim. Weather Service publications for this particular area do not differentiate rainfall in respect to the influence of topography or elevation to the accuracy needed to make a definitive evaluation. That is, the published 100-year storm shown for Kohl's Ranch cannot be distinguished as being different from that on top of the Rim. Comparing this single amount with the varying amounts of rainfall estimated for different areas along and adjacent to the Rim for the September 1970 storm does not take into account that rainfall on top of the Rim is usually greater than at Kohl's Ranch. Hence, this storm may have been near the 100-year frequency throughout the area even though twice as much fell on top of the Rim as fell in the Kohl's Ranch area.

RUNOFF

5. *The Labor Day storm established new peak flow records for central Arizona. Tonto Creek's peak discharge was at least twice the 50-year flood which is no greater by comparison than several other widely separated streams in central Arizona.*

Based upon data published by the United States Geological Survey and comparison with previously published data, the flood on Tonto Creek a short distance below Kohl's Ranch exceeded the 50-year flood by 1.9 or almost two times as much as would be expected from the 50-year flood.

This ratio is based upon a flow of 18,400 cfs measured by the Geological Survey for the 24 square mile watershed above Tontozona located a short distance below Kohl's Ranch. Forest Service estimates of the peak flow at the Highway 260 Bridge at Kohl's Ranch without any reduction for the volume of debris, was 28,000 cfs. The watershed above this point is 21.4 square miles giving a peak flow of 1,307 csm as compared to 767 csm at the point measured by the Geological Survey.

Comparatively, the flood on Christopher Creek was not such a rare event although the stream channel was extensively damaged. There, near the Christopher Creek Recreation Area, the flood was 1.2 times the 50-year flood.

Of further interest is the relative magnitude of the floods on these two streams in comparison with measured peak flows throughout central Arizona as shown in table 5. At the locations where peak flows were

Table 5 - Selected discharge for the September 4-6 storm as reported by the U. S. Geological Survey. 1/

Location	Drainage Area Sq. Mi.	Discharge in Cubic Feet Per Second	Recurrence Interval (Yrs)
Tonto Creek near Gisela	430	46,300	1.2 x 50 yr. 3/
Rye Creek near Gisela	122	44,400	2.2 x 50 yr. 3/
Tonto Creek above Gun Creek near Roosevelt	675	53,000	1.1 x 50 yr. 3/
East Verde River near Pine	6.65	2,820	50 + 4/
Webber Creek above West Fork Webber Creek near Pine	4.92	1,220	15 4/
Sabino Creek near Tucson	35.5	7,550	100 + 4/
Dry Beaver Creek near Rimrock	142	26,600	2.0 x 50 yr. 3/
Sycamore Creek near Sunflower	53.4	16,100	1.9 x 50 yr. 3/
Hassayampa River near Wickenburg	417	58,000	2.3 x 50 yr. 3/
Tonto Creek below Kohl's Ranch at	24.0	18,400	1.9 x 50 yr. 3/
State Highway 260	21.4 2/	28,000	2 x 50 yr. plus 3/
Christopher Creek near recreation area	24.4	11,900	1.2 x 50 yr. 3/

1/ "Floods of September 1970 In Arizona, Utah, and Colorado" Water Resources, Report No. 44. Arizona State Land Department. Prepared by R. H. Roeske, U. S. Geological Survey, Phoenix, Arizona, April 1971.

2/ Forest Service data not USGS.

3/ Not provided by USGS - Determined from, "Magnitude and Frequency of Floods in the United States." Geological Survey Water-Supply Paper 1683.

4/ "Water Resources Review for September 1970" USGS pp. 5 and 6.

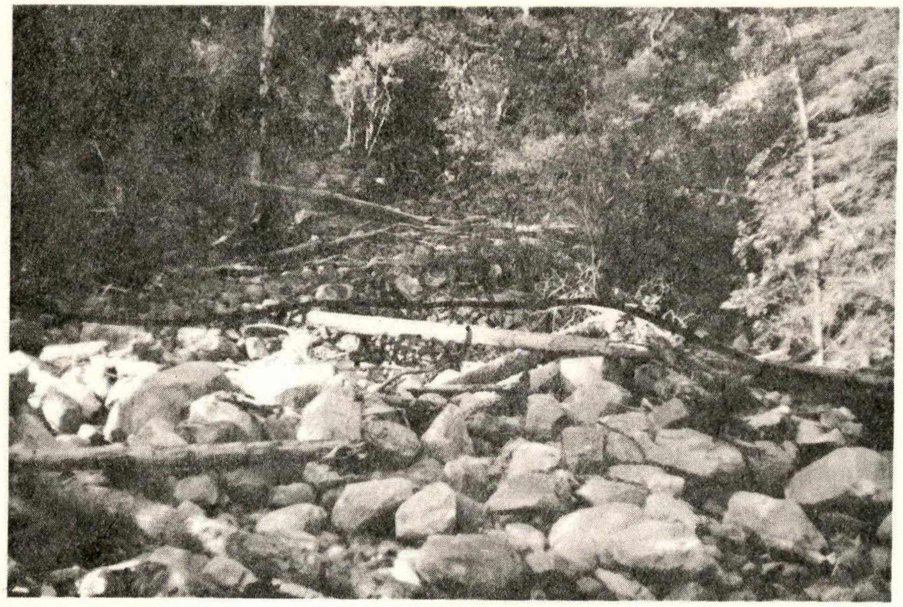


Photo 4 - Old flood plains and terraces in the vicinity of Tonto Creek Fish Hatchery show that floods similar to the September 5 flood occurred in the past. Vegetation grows out of the old lichen covered debris mass in the background in contrast to the recent deposits in the foreground.

Photo 5 - Close-up view of old flood deposits along Tonto Creek.

determined by the Geological Survey, Tonto and Christopher Creeks did not flood with relatively as great a magnitude as some other streams. This again, points out that much of the losses incurred on Tonto and Christopher Creeks resulted because the developments and people were vulnerable. If the developments and people had not been present, a larger flood could have passed without fanfare as happened on other streams. Streams in all directions from Tonto Creek both above and below the Rim rampaged. For example some of these include East Verde Creek to the west of Tonto Creek and Hunter and Haigler Creeks to the east. Heavy runoff occurred above the Rim in the headwater drainages of Chevelon and Clear Creeks. In a southwesterly direction extremely high flows were measured in Sycamore Creek. Overall, damages along these streams consisted of washed out highways and bridges, loss of life, power failures, stranded travelers, and damaged dwellings.

Peak flow measurements at 77 gaging stations in the State show that 42 of the peaks exceeded the maximum of record. Preliminary published records indicated twelve of these peaks exceed the 50-year flood and several will exceed the 100-year flood.

The frequency of occurrence of observed peak flows on subdrainages within the Tonto Creek Watershed varied considerably. No attempt has been made to establish such frequencies due to the lack of a suitable method for small ungaged areas. The fact that the rainfall over the watershed exceeds the 100-year storm and the peak flow on Tonto Creek at Kohl's Ranch was at least twice that of the 50-year flood is sufficient to establish the September 5 flood as a major hydrometeorological event worth study and evaluation. Table 5 lists peak flows in cfs and csm for Tonto Creek and selected drainages in Arizona.

6. *This most recent flood is the most destructive recorded for Tonto Creek but geologically speaking it is a natural phenomenon of unpredictable occurrence.*

The relationship between rainfall amounts and flood frequency is not a constant. Rainfall intensity and antecedant moisture conditions cause different magnitudes of floods even though total storm rainfall amounts remain equal. That is, there is no established reliable relationship between the 100-year storm and the 100-year flood. Fortunately, the September 4-6 storm was well distributed in time and soils did not contain as much water from previous rainfall as they might have.

This flood is not the first flood of consequence in Tonto Creek, but it is the most destructive of any observed by recent man. A flood crest of 12 feet was noted at the Tonto Creek Bridge in August

of 1964. The 1964 event was caused by a local storm of approximately 2 inches of rainfall which also centered over the Upper Tonto and Horton Creek drainages. However, this storm destroyed only stream fishery improvements. There is widespread geomorphic evidence within the Tonto Creek Watershed which shows that severe flood damage to stream channels has occurred before. This most recent event is only one in a series which periodically carves these channels deeper into bedrock to maintain equilibrium with a larger drainage network. The opportunity to observe and study such events - tragic though they may be - does not often occur in one man's lifetime.

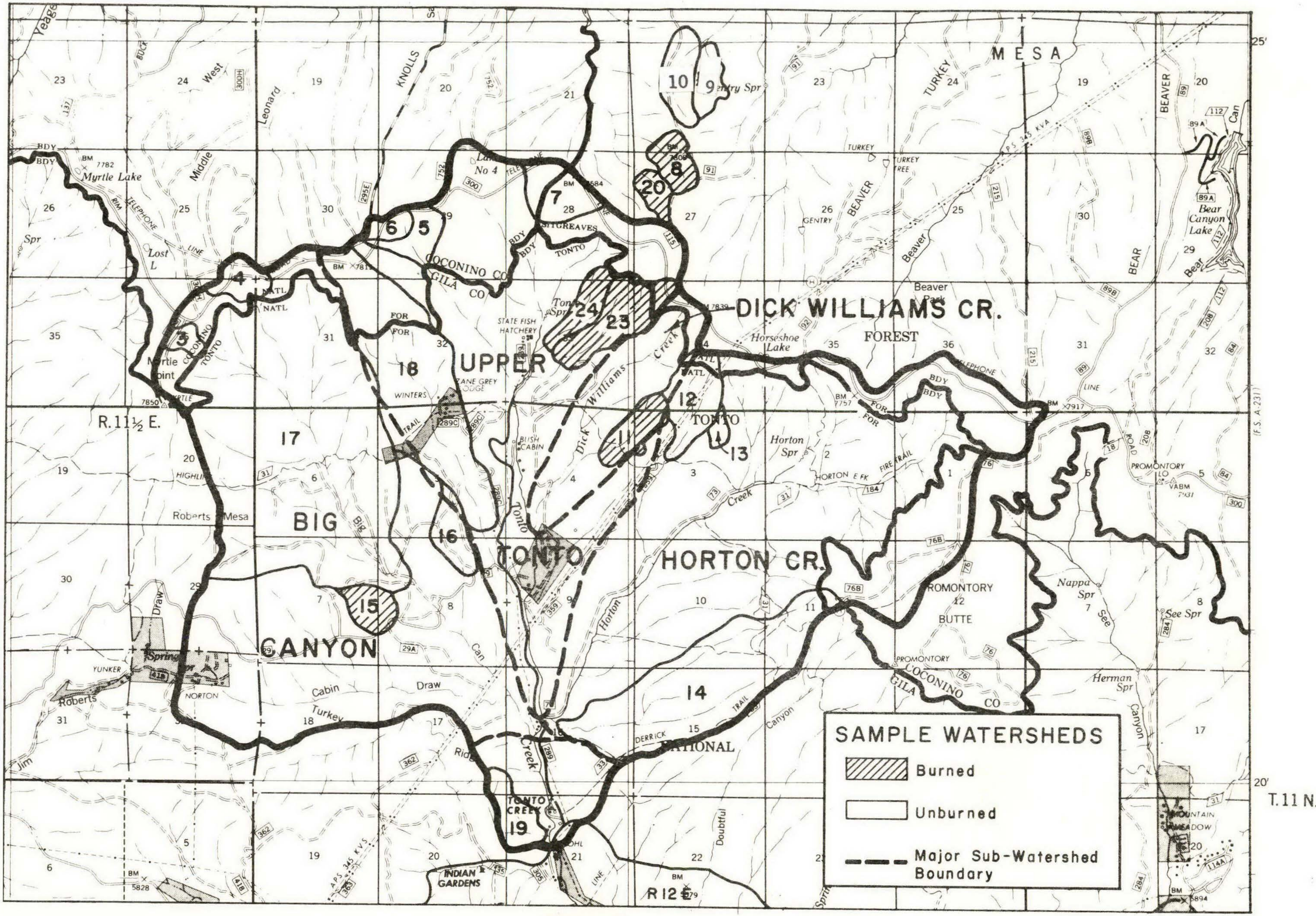

SAMPLE WATERSHEDS
Burned
Unburned
Major Sub-Watershed Boundary
DICK WILLIAMS CR.
UPPER
BIG
TONTO
HORTON CR.
CANYON
MESA
R.11½ E.
R 12 E
T.11 N.

Figure 5

AN ANALYSIS OF THE FLOOD ON TONTO CREEK

RUNOFF CHARACTERISTICS

7. *Twenty subwatersheds within and adjacent to Tonto Creek were field sampled and analyzed.*

Twenty watersheds within or adjacent to Tonto Creek were field sampled for analysis. The locations of these sample watersheds are shown in figure 5. These watersheds were selected to insure that channel measurements did not reflect appreciable changes caused by scouring or deposition during the storm. High water marks for all samples were conspicuously evident. In addition, sample watersheds were selected to represent a wide variety of soils, vegetation and other characteristics affecting rainfall-runoff relationships. Sample watersheds included such contrasts as: areas burned by wildfire as compared to areas in near primordial forest condition and, areas of relative flat terrain as compared to areas with precipitous slopes. Aerial photographs taken before and after the flood provided for an objective comparison of relative damage between major subdrainages such as Dick Williams, Horton, and Upper Tonto Creeks which were damaged so severely as to preclude reliable flow estimates.

Through analysis of rainfall intensity, watershed condition and physiographic characteristics, the rainfall and runoff required to produce the observed peak flows was determined. The primary method of analysis utilized a constructed dimensionless mass rainfall curve and over 800 computed incremental hydrographs used to match variable amounts of storm rainfall with observed peak flows by trial and error. The incremental hydrograph method is described in Soil Conservation Service Technical Paper 149 dated January 1968.

8. *Rainfall from as low as 4 inches to as high as 18 inches is estimated to have fallen within a comparatively small area due to topographic influences.*

Based on this analysis it is highly probable that total storm rainfall in the headwaters of Tonto and Dick Williams Creeks was as high as 18 inches. In the rain shadow created by Myrtle Point, as little as 4 inches may have fallen. The extreme variation in rainfall shows good correlation with the contrasting topography within the watershed and the general direction of storm movement. Previous studies have shown these relationships to hold true in Arizona for seasonal and annual precipitation.

9. *Variations in rainfall caused more of the variation in peak flow than did any other factor.*

Peak flows on the sampled watershed averaged 2,064 csm and ranged from 477 csm to 4,396. These peaks, determined from high water marks and standard slope-area techniques, are tabulated in table 6. Note that the peak flow for Tonto Creek at Kohl's Ranch was 1,307 csm. An analysis of the peak flow data showed that peak flows in csm were geographically patterned. This pattern can be accounted for only by variation in amount or intensity of rainfall. Factors such as soil type, vegetation condition and steepness of slope were not the principal controlling factors in causing the great variations in runoff from different geographic areas in this watershed for this particular storm.

10. *Computed runoff varied from less than one area inch to over twelve area inches.*

As determined by this analysis, total runoff averaged almost 3 area inches for the entire study watershed (table 6). Over 12 inches of runoff occurred on sample Watershed 23 where soils are shallow, rocky, and highly impermeable and rainfall was 16 inches. Less than one inch of runoff was produced on sample Watershed 17 where more permeable soils exist and storm rainfall was less than five inches.

11. *Hydrographs of reconstructed runoff indicate that smaller tributary Watersheds were sustained at high levels of flow for periods of over one hour.*

Runoff from the storm occurred during much of the time that rainfall was in progress. However, hydrographs of reconstructed runoff indicate that the peak flows in all sampled small Watersheds were reached early in the approximately 1-1/2 hour period of intense rainfall which occurred on Saturday afternoon, September 5, and were sustained at that stage for the remainder of the intense period giving a relative flat and prolonged peak. The hydrograph of reconstructed runoff in Tonto Creek at Kohl's Ranch exhibits a more typical pronounced peak due to the much longer time required for this larger Watershed to peak. The time required to peak for each Watershed is related to physical characteristics which determine the travel time of runoff from the time rainfall reaches the ground until it passes some point downstream. The time to peak for each sampled Watershed is shown in table 6.

The significance of a critical period of runoff contributing to peak flows can be seen in sample Watershed 15 which produced almost 11 inches of runoff from the total storm. Its peak flow of 376 cfs was raised by

Table 6 - Summary of runoff from sampled watersheds within and adjacent to the Tonto Creek Watershed.

Watershed No.	Location of Highwater Measurements	Area	Computed Rainfall	Computed Peak Flow		Computed	Time To Peak	
							Hr.	Min.
		ac	nearest .5 in.	cfs	csm	area in.		
3	Above Rim	28	12	107	2,488	6.87		18
4	Above Rim	59	6	86	937	1.84		23
5	Above Rim	101	5	91	577	1.44		35
6	Above Rim	9	9	20	1,394	3.98		22
7	Above Rim	127	5	115	581	1.23		32
8*	Above Rim	79	12	359	2,909	6.87		19
9	Above Rim	68	14.5	242	2,279	5.40		21
10	Above Rim	118	13	343	1,868	4.36		26
11*	Face of Rim	97	9.5	297	1,953	4.49		19
12	Face of Rim	162	8	329	1,303	3.22		18
13	Face of Rim	19	17	128	4,354	11.36		8
14	Below Rim	670	8.5	1,081	1,032	2.22		43
15*	Below Rim	68	14	376	3,540	10.81		17
16	Below Rim	92	9.5	259	1,805	4.75		18
17	Below Rim	2,180	5	1,626	477	.98		43
18	Below Rim	725	11.5	2,540	2,241	5.84		47
19	Below Rim	130	7.5	270	1,325	3.25		21
20*	Above Rim	48	8	117	1,568	3.56		19
23*	Face of Rim	195	16	1,342	4,396	11.48		23
24	Face of Rim	98	16	650	4,259	12.60		21
Tonto Cr.	Kohl's Ranch	13,710	8	28,000	1,307	2.91	1	31

* Burned Watersheds

only 1-1/2 area inches of runoff, or 15 percent of total runoff in a period of 17 minutes. Runoff continued to flow at around 376 cfs for over one hour before it began to recede. Similarly, a gaged watershed on Workman Creek on the Sierra Ancha Experimental Forest peaked at 236 cfs and maintained a flow above 200 cfs for 1 hour and 35 minutes.

12. *Even though unprecedented amounts of rainfall fell in the storm of September 5, the Tonto Creek Watershed could have withstood these amounts without damage if the rainfall had been evenly distributed in time.*

Although the total amounts of rainfall were beyond anything previously experienced, the peak flows from Tonto Creek would have been inconsequential if storm rainfall had been evenly distributed in time. The destructive sustained peaks experienced were caused by the intense rainfall which fell during a period of approximately 1-1/2 hour on the afternoon of September 5.

OBSERVATIONS OF RUNOFF IN RELATION TO ON-SLOPE AND STREAM CHANNEL DAMAGES

13. *Very little on-slope damage has been observed while channel damage is severe and widespread.*

The phenomenon of a once-in-a-century storm cannot be adequately described in quantitative terms alone. The visual observations of several experienced field hydrologists offer much to describe the manner in which raindrops coalesced, moved across the ground's surface, concentrated in small unimpressive rivelets and then rapidly developed into death-dealing torrents of destruction. There is one anomoly that stands out above all others--it is the lack of evidence of excessive on-slope damage. Very little damage was observed on-slope where the runoff originated. In fact, over most of the watershed it was not strikingly apparent by slope observations that any unusual event had occurred. It was only after the runoff became concentrated in steep channels that evidence of spectacular dimensions was left to show that a storm of unprecedented magnitude had occurred.

Topographically, the study watershed can be divided into three distinct areas (figure 6). A series of traverses through the watershed from Kohl's Ranch to the watershed boundary show basic similarities in profile. They first rise in elevation gradually for a distance of about 3 miles to the base of the Mogollon Rim and then pitch upward steeply for a distance of about 1 mile. At the top of the Rim, the gradient levels off sharply onto a relatively flat bench which borders the Rim. This lip or shelf encircling the Rim varies in width form only a few hundred feet to a distance of three quarters of a mile.

Each of these three areas is discussed in the following paragraphs in relation to runoff and damage. Areas affected by past wildfires are not included in this description of typical hydrologic evidence. A separate discussion on burned areas occurs in a following section.

14. *Runoff was abnormally high on top of the Mogollon Rim, but practically no on-site or channel damage occurred.*

The bench on top of the Rim has soils which are generally shallow, medium-textured and were developed from the Coconino sandstone. 1/ About 34 percent of the ground surface is covered by coarse rock fragments. Slopes average 6 percent and are generally covered by Ponderosa pine and Gambel oak with typically associated mountain bunch grasses. Needle cast provides excellent ground cover.

The potential for surface runoff from this bordering lip of the Rim is high. This is due to the shallowness of the soils and their rock content. However, excluding the main drainage channels, evidence of runoff was found only where bedrock was at or very near the surface or immediately below cross-drains along the Rim Road. In those cases where there was little or no soil over bedrock, accumulated litter was washed away and immediately downslope, rill-like channels were cut into the thick litter which had accumlated over a long period of time in indistinct depressions. Seldom did the rilling cut through the duff layer under the litter. The lack of litter displacement on-site indicates that the source of the runoff from this area moved through the soil and litter layer and did not reach sufficient depths to float the surface layers of litter except on an estimated 10 percent of the area where bedrock at or near the surface restricted infiltration.

Natural drainage channels on top of the Rim, some poorly defined, showed practically no damage although water ran unusually deep as evidenced by distinct high water marks. This was due to the low gradient and hence low velocities in the channels. Average computed channel velocities were about 6 feet per second. As stated previously water ran deep and down snags and other debris which had remained in place for many years were floated and moved varying distances downstream.

15. *Channel damage on the face of the Rim was the worst in centuries while slope damage was negligible except for isolated mass movement.*

Once the runoff in the channels reached the brink of the Rim and gathered momentum as it cascaded down with increasing channel gradient,

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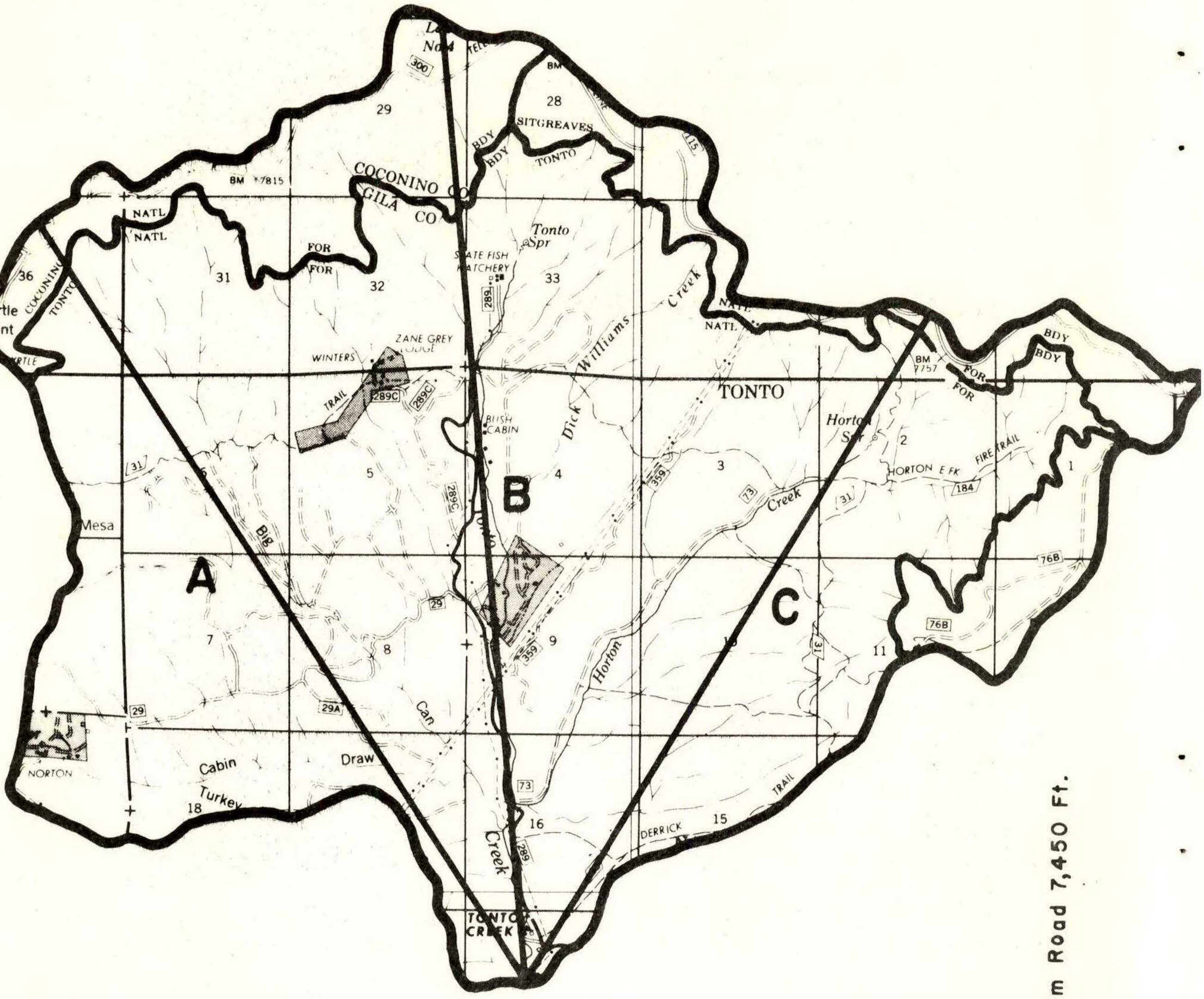
1/ See "East Verde Soil Survey Report" By Howard Broaderick, U.S.F.S., 1971.



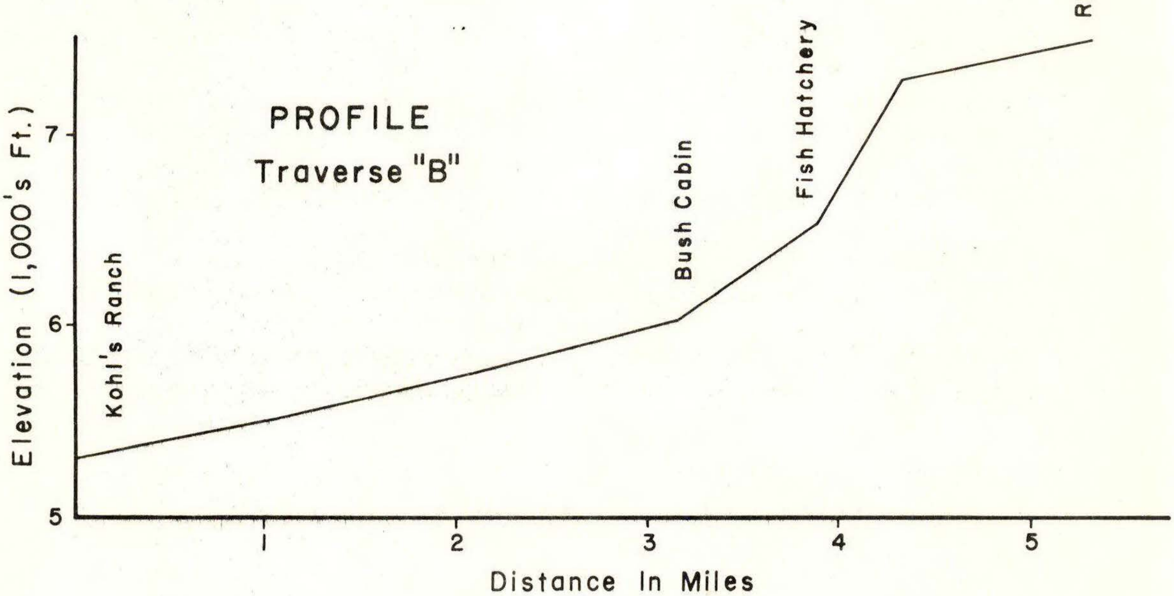


Fig. 6. Profile of Tonto Creek Watershed.

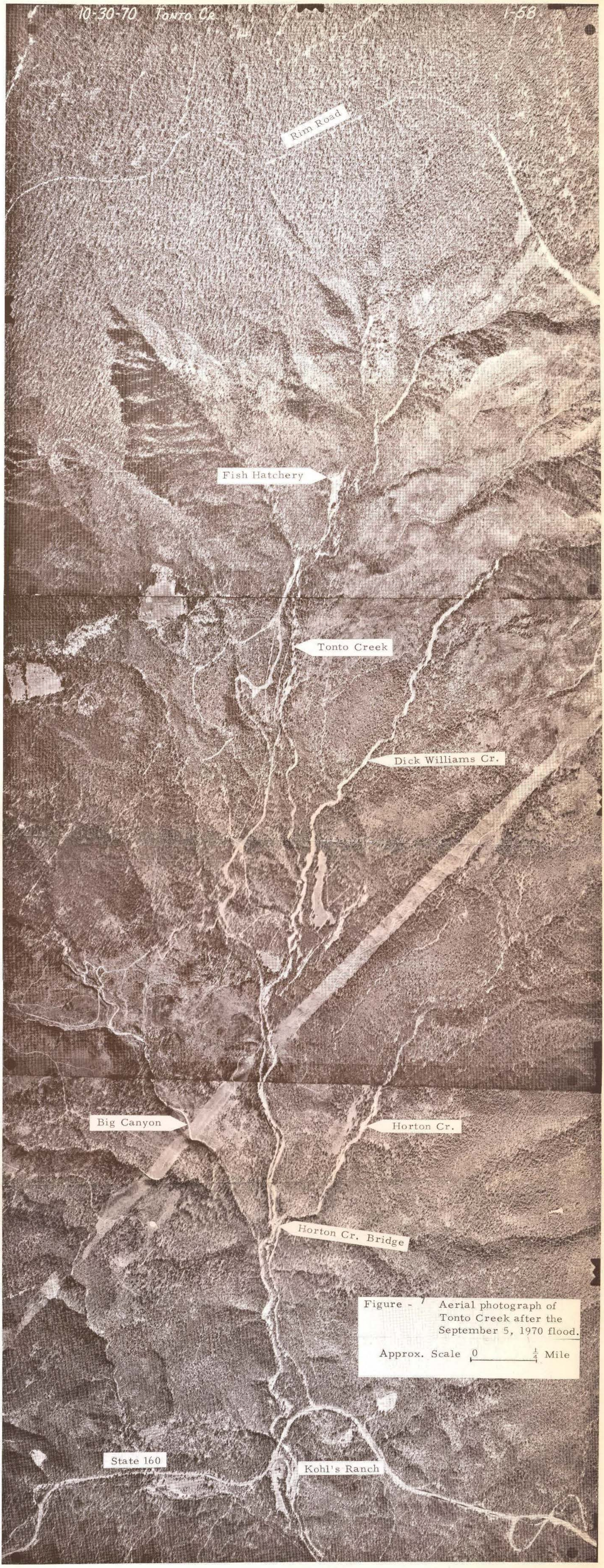


Figure - 7 Aerial photograph of Tonto Creek after the September 5, 1970 flood.

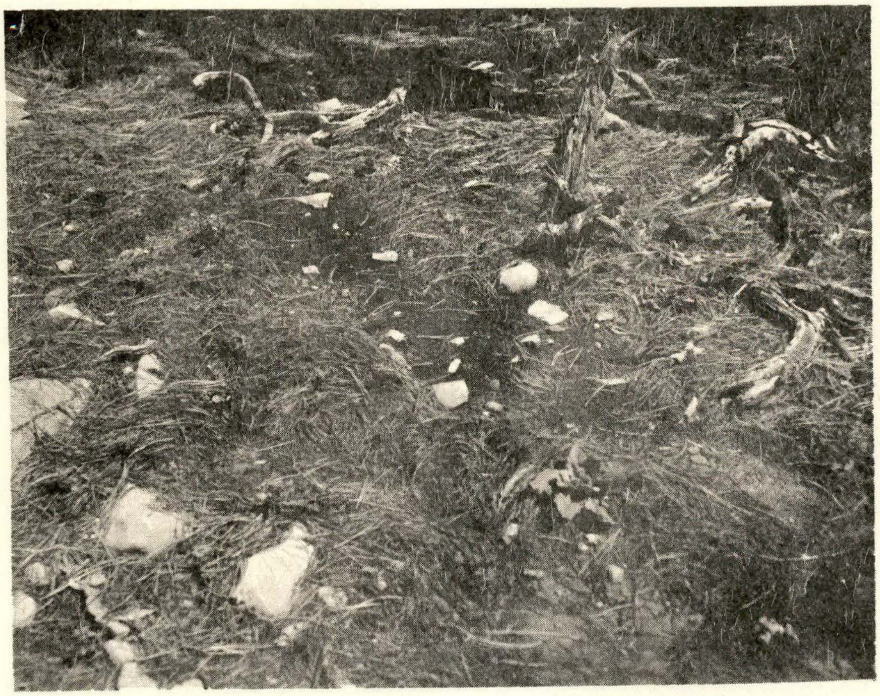


Photo 6 - Very little on-slope erosion damage occurred. Where concentrations of surface runoff formed, rivulets often moved surface litter down slope without disturbing underlying organic matter.

Photo 7 - Above and near the top of the Rim channel flow ran unusually deep, but no severe channel damage was observed in these headwater areas until channel gradients began to steepen.

Photo 8 - Channel cutting just below the Rim consisted mostly of widening due to exposure or nearness of bedrock to the surface.

Photo 9 - Channel widening into colluvial slopes provided the source of large amounts of debris consisting of rocks, soil and undermined trees.

Photo 10 - Large amounts of rock, soil, and plant debris were added to the flood waters towards the base of the Rim due to an increasing volume of water, debris daming and the availability of more extensive colluvial deposits.

Photo 11 - As the channel gradients decreased at the bottom of the Rim, large boulder and debris piles were deposited.

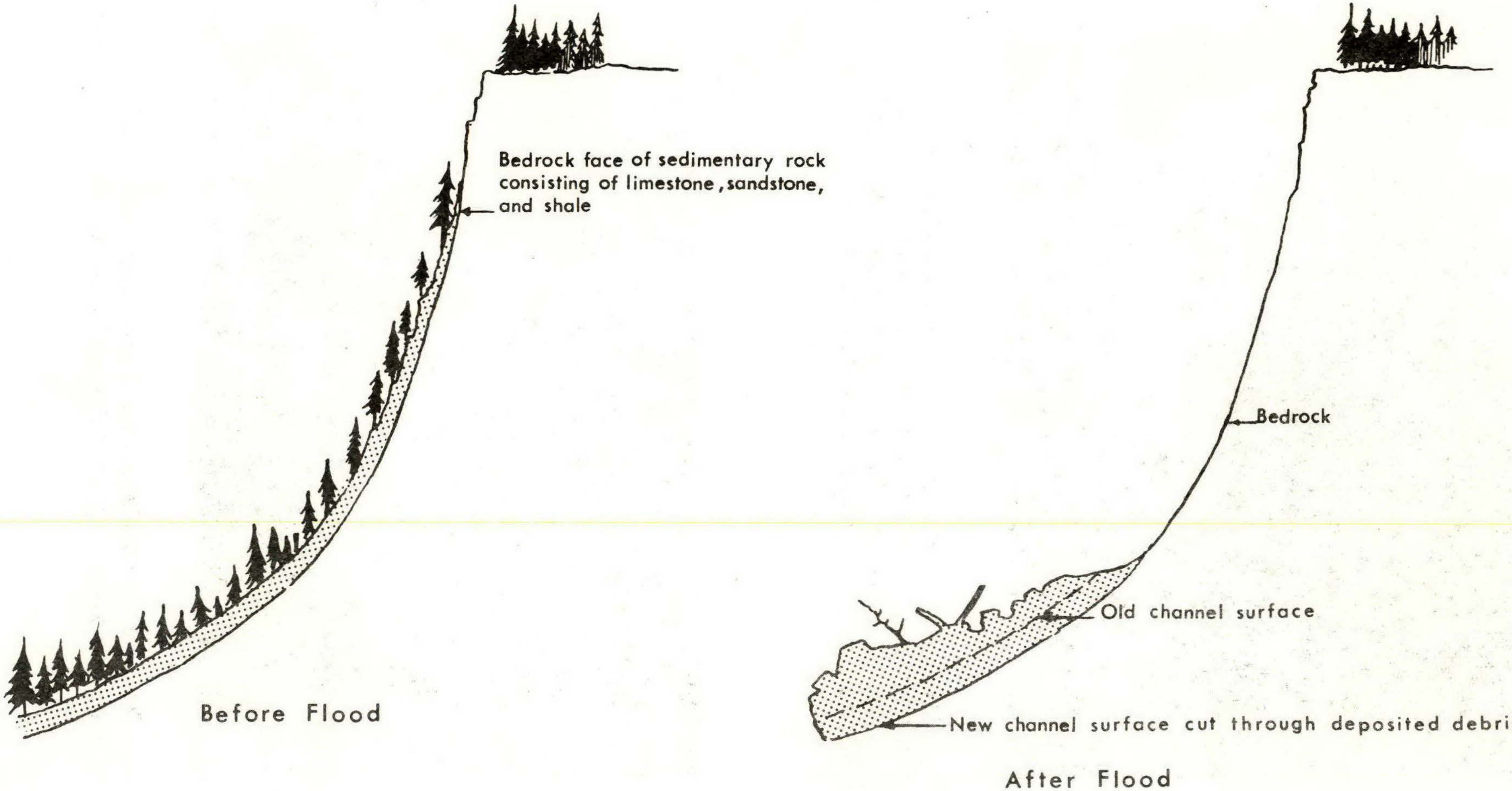
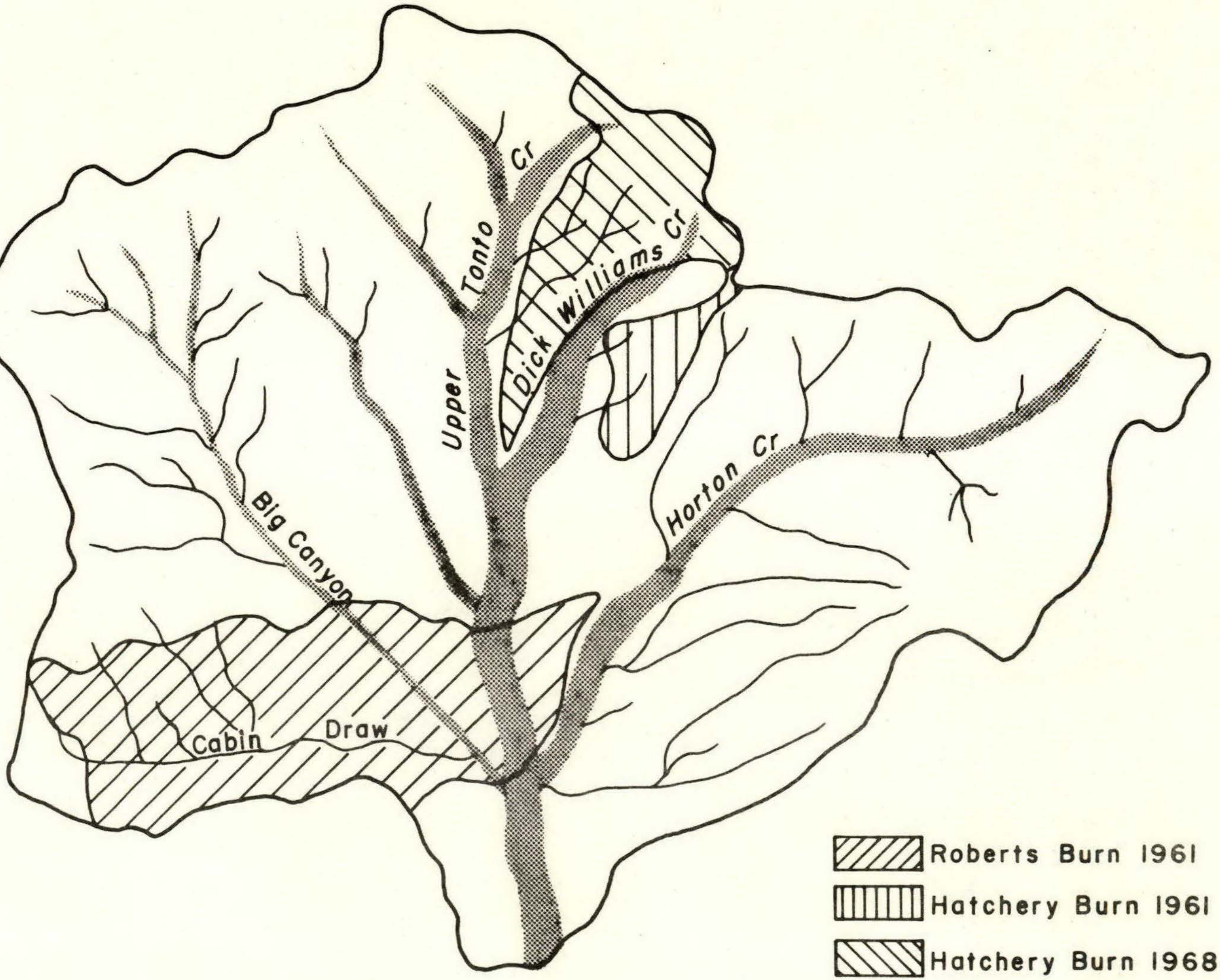


Figure 8. Illustration of mass movement of accumulated channel materials down face of Mogollon Rim during flood of September 5, 1970.



Relative channel damage in relation to areas burned intensely by wildfire.

Figure 9

damage became spectacularly evident. As the channel gradients steepened to about 35 percent, uprooted trees were observed for the first time and the channels showed considerable disruption from cutting and redeposition of materials along those reaches where gradients diminished.

On-site runoff observations on the face of the Rim were similar to those on the bench above in that no appreciable on-slope damage was observed. However, more litter movement was evident. Runoff from this zone had only a very short distance to go before reaching a defined channel, and, therefore, the degree of surface disturbance is not suitable for direct comparison with the contrasting area above.

The face of the Rim has the potential for yielding large amounts of surface runoff. Soil materials consist mainly of shallow pockets and strips of extremely stony and sandy colluvial accumulations on slopes of 40 to over 100 percent. As a result, vegetation is more sparse than on top of the Rim. Species composition also varies greatly with available soil moisture and elevation. This creates microcosms of plant-life zones which range from alligator juniper to Douglas fir.

Soils became saturated with water on the face of the Rim early in the storm. When the large volume of rainfall fell on September 5, it moved directly into the nearby channels.

Sample measurements showed that water velocities within major drainages carrying runoff down the face of the Rim ranged as high as 30 to 40 feet per second where channel roughness was low such as in bedrock chutes. Physical damage was beyond general comprehension. Colluvial and deposited bed load material that had accumulated in stream channels along the face of the Rim was moved to the base of the Rim at the point where channel gradients begin to diminish (fig. 8).

The combination of saturated soil and channel materials on near vertical slopes, and prolonged excessively high streamflow provided the conditions necessary for moving the large masses of debris. Although not observed while the storm was in progress, the sequence of events can be recreated from the evidence which remains.

16. *Stream channel beds composed of rock and soil accumulating over a period of centuries literally slid down the face of the Rim.*

The smooth bedrock inclined at such steep angles provided little resistance once channel and side slope materials became saturated. Undercutting by runoff below enabled the massive weight of this rock, soil and water mixture to literally slide on the well lubricated bedrock surface. Mass movements of the soil and channel materials dammed the channels. This was followed by diversion or breaching. Then subsequent damming occurred downstream as the accumulated uprooted trees and other debris in the initial dams were carried downstream by the surges of escaping water.

17. *Evidence of on-slope runoff below the Rim was typical of that frequently found following summer thunderstorms.*

Below the Rim, a greater variety of conditions exists. Soils are complex, ranging widely in depth and texture. Vegetation is predominantly ponderosa pine which varies in stand density and quality. The steepness of slope also varies greatly, but the average is less than twenty percent.

Evidence of surface runoff is more obvious on this area below the Rim than in any other. This is attributed to the sparse ground cover found at the lower elevations on fine textured highly impermeable soils. In these areas there was not enough litter to form a continuous mat through which the surface runoff could flow. Instead, litter was easily detached and washed from one location to another. Even near the ridge tops, this washing occurred. However, this in itself is not evidence of an abnormal storm. Litter movement is often observed on these areas following intense summer thunderstorms.

18. *Channel flows originating below the Rim were relatively non-destructive compared with major drainages which began above the Rim or on its face.*

Evidence of channel flow originating below the Rim is similar to that observed on the bench on top of the Rim. High water marks show unusually high flows but only minor channel damage. But, those drainages which had headwaters originating on or above the Rim in the high rainfall area on the north and northeastern side of the watershed were heavily damaged.

19. *Stream channel damage was severe on more than eight miles of major channels in the Tonto Creek. Dick Williams Creek, with a watershed of only 558 acres, was probably the most severely damaged stream channel in the state.*

The eight miles of most severe stream channel damage occurred on three drainages passing through this lower section of the watershed (figs. 7 and 9). Two of these are major stream channels which drain large watersheds. Upper Tonto Creek includes approximately 4,000 acres and Horton Creek slightly over 5,000 acres. Dick Williams Creek is the third heavily damaged drainage. With a watershed area of only 558 acres, Dick Williams Creek contains the most extensively damaged channel along the Rim and probably anywhere in the State as a result of the September storm. Dick Williams Creek was the major contributor of uprooted trees and bedload observed in the Tonto Creek flood downstream.

Prior to the Labor Day weekend storm, Dick Williams Creek could be described as a small but aesthetically beautiful high mountain trout stream. Its flow slowly found its way downstream in a "brook-like" channel lined with trees, shrubs and moss and lichen covered rocks. Through much of its course, this stream was completely covered by a canopy of trees some of which had stood for centuries. Figure 9 shows the location of Dick Williams and the other major streams that form that portion of Tonto Creek comprising the study area and the relative magnitude of damage that occurred on each of them. Figure 11 is an aerial photograph showing relative stream channel damage at the confluence of Dick Williams Creek and Upper Tonto Creek.

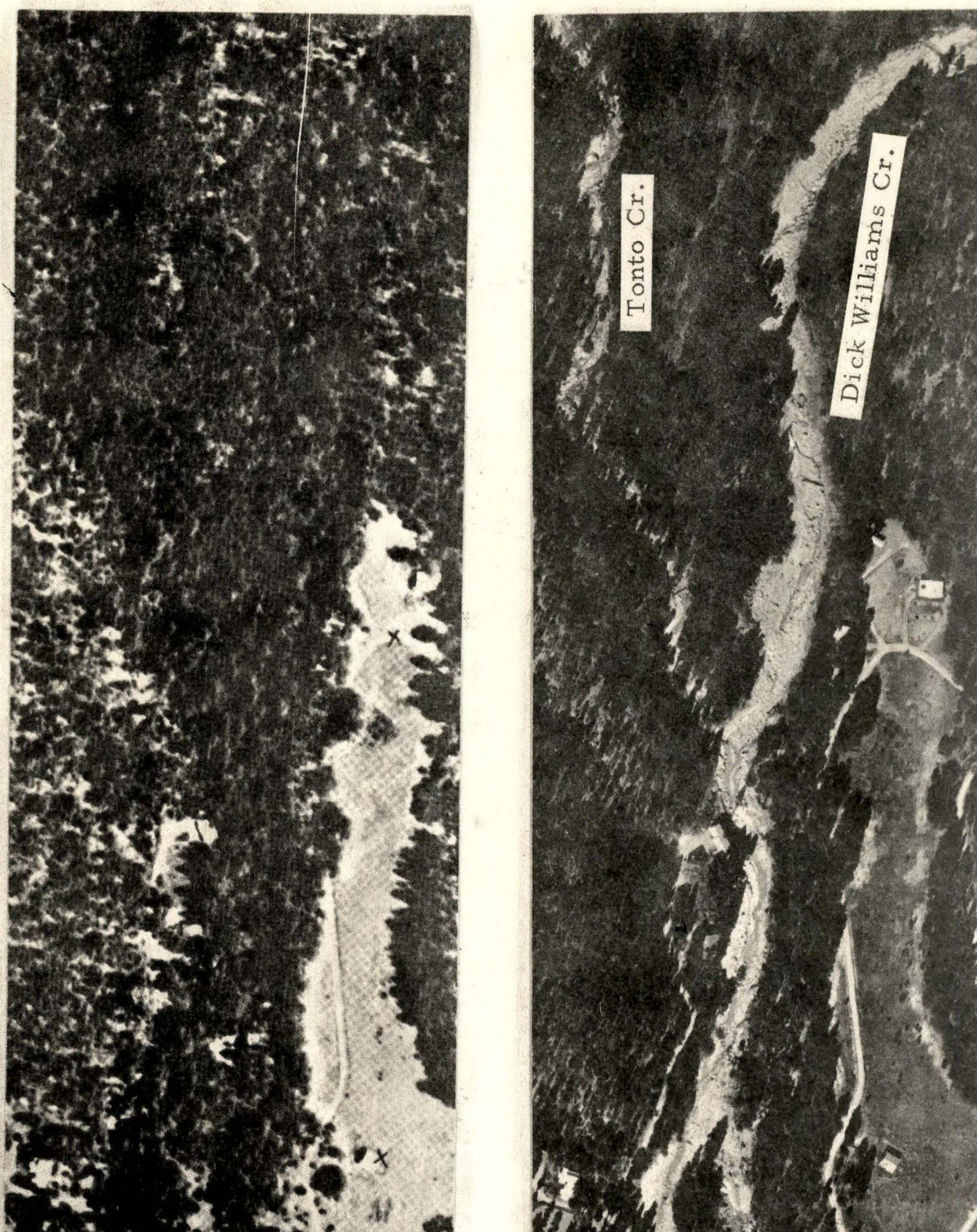
20. *The pre-flood channel materials in Dick Williams Creek are gone from most of its length and a 100 foot wide gutted trench now exists.*

After the ravages of the flood had ended, Dick Williams Creek, through much of its course, was a gutted channel over 100 feet wide from which most material above bedrock had been removed or churned up. Likewise, the trees that had once lined and shaded its banks were strung out in debris piles for many miles downstream. In places the channel is as if it had been scooped clean by some huge behemoth machine. Its diminsions range as high as an estimated 50 feet in depth - from the stream channel bottom to the high water mark - and over 100 feet wide (fig. 11).

Although Upper Tonto and Horton Creeks were damaged extensively and similarly, Dick Williams Creek differs by the way it was swept clean for much of its length. In contrast, rubble and debris is more evenly distributed throughout the length of all other drainages observed. Also, Dick Williams was swept clear of vegetation to a greater width and more uniformly throughout its length than any other adjacent or nearby drainage.

21. *Boulder deposits in severely damaged channels are 10 to 30 feet deep and up to one-quarter mile long.*

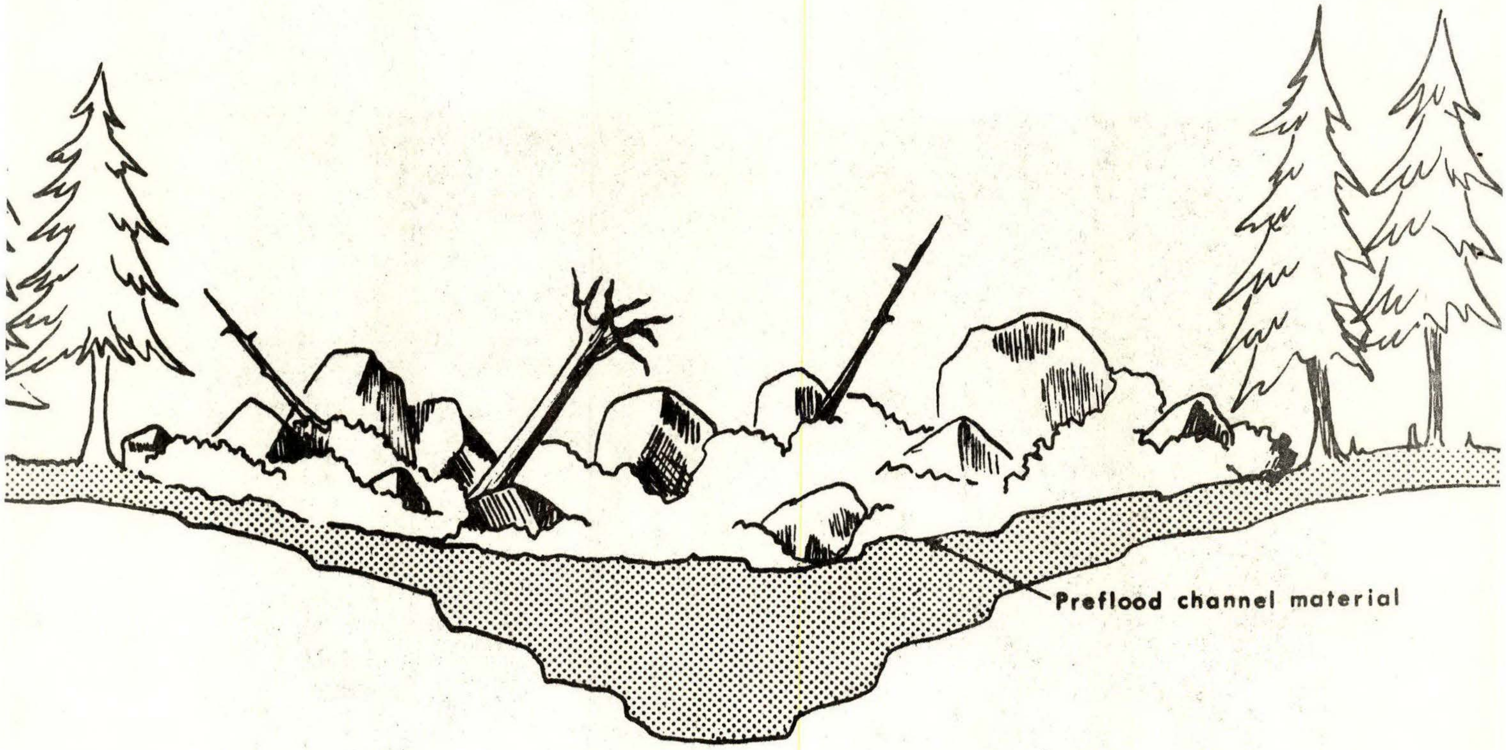
Channel damages can be categorized into channel scour, cut banks, boulder accumulations and uprooted trees and related debris. As described before, the channel materials of Dick Williams Creek were almost completely removed and deposited downstream. More typical of other channels was alternate scouring and deposition. Stream bottom vegetation on these channels was sometimes only bent over. In many places, the flood left vertical streambanks in deep alluvial materials. This type of damage is associated most with curves in the channel and diversions caused by debris dams which directed flows against streambanks.



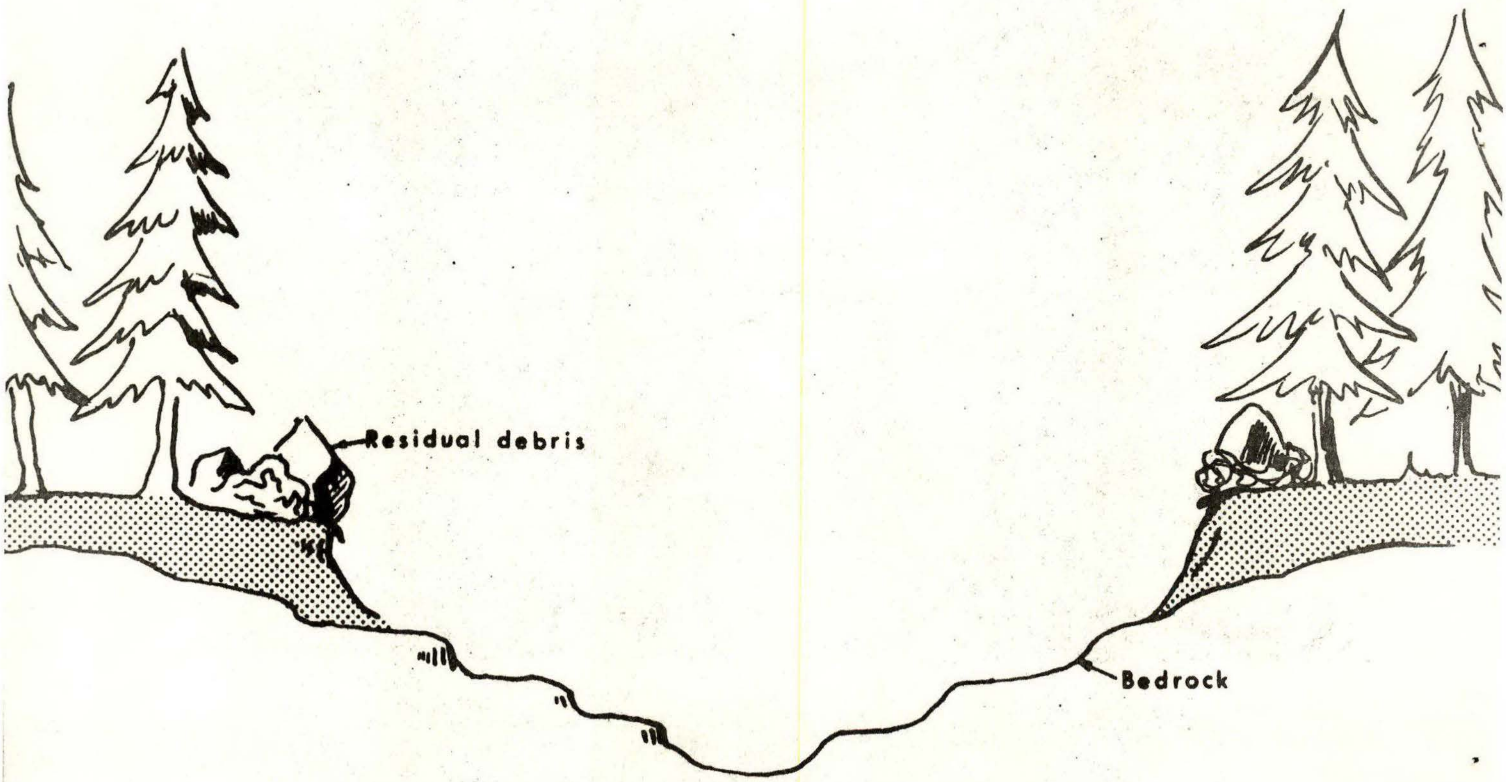
Before Flood

After Flood

Figure - 11 Aerial view of stream channel damage in Lower Dick Williams at confluence with Upper Tonto Creek before and after September 5, 1970 flood.



Early Stage Of Flood



After Flood

Figure 10. Illustration of deposition of debris in channels followed by erosion of deposited debris and preflood channel materials during Flood of September 5, 1970.

Photo 12 - Dick Williams Creek is now a gutted channel through its entire length where prior to the flood it was a "brook-like" channel lined with trees, shrubs and moss covered rocks.

Photo 13 - Debris dams temporarily reduced the velocity of the floodwaters allowing alluvial deposits to build up. As the dams were breached cutting of the deposits began to occur again.

Photo 14 - Once the velocity of the flood waters increased after the debris dams broke, the channels were again scoured clean.

In almost every channel, large boulders have accumulated or have been exposed by the scouring of finer materials from around them. Large piles and deltas exist where channels widened and reduced the depth of flow or when their gradient flattened causing a drop in velocity and hence carrying power. The boulder deposits are 10 to 30 feet deep often extending across the width of the channel. They contain materials from gravel size to six cubic yards per rock. In some areas, water is diverted to one side, while in others it flows through or under the boulders. Deposits are not continuous, but occur in accumulations of a few yards to one-quarter mile in length.

22. *Uprooted trees increased the destructiveness of the flood flow more than any other factor. Over 100 acres of standing trees were uprooted and swept away.*

Uprooted trees increased the destructiveness of the flood downstream more than any other factor. Full length trees were observed floating upright in deep water. As large trees were undercut and fell, they commonly sheared limbs from adjacent trees to heights of 50 feet or more. Standing trees also bear witness by the scars they show of being flailed far above the high water mark. This writhing mass of water, trees, and boulders periodically lodged and backed up large volumes of water. The increased depths enabled large trees to be deposited on high banks 20 to 30 feet above the streambed. Most trees were completely debarked, roots and limbs were broken off and abraded almost flush with their trunks. As the debris dams gave way, deep flood waves carried the debris farther downstream to catch on some obstruction to repeat the cycle with increasing destructiveness. The Horton Creek bridge was the most resistant object encountered in the watershed, and the tremendous volume of material trapped at this point may have saved the resort facilities at Kohl's Ranch from damage. In the absence of this trap, the debris could have lodged against the Highway 260 Bridge, diverting the flood at this point into nearby buildings.

There were at least 100 acres of timber uprooted by the flood in the Tonto Creek Watershed on which grew approximately 4,000 trees (more than 1,400 were over 12 inches in diameter) with a total volume of about 24,000 cubic feet or over one-quarter million board feet.

23. *The storm characteristic that contributed most to the damaging aspects of the flood was the long duration during which intense rainfall fell. This period of about 1-1/2 hours provided a continuing flow of water to transport dislodged masses of rock, soil, and dismembered trees.*

The great disruption which took place in the channels such as changing the location of springs in Dick Williams Creek, possibly sealing a fault and converting the lower reaches of Horton Creek into a perennial stream and transporting thousands of cubic yards of debris could not have occurred without a large continuous supply of water as a transporting medium.

The total effect of channel damage was to temporarily destroy a valuable recreation and fishery resource; create a potential flood danger from future storms due to deposited debris, channel changes and loss of channel carrying capacity; create a potential insect epidemic from uprooted trees; and, the development of a fire hazard where concentrated inflammable material was deposited in heavily used recreation areas.

PAST WILDFIRES AND THEIR AFFECTS ON FLOOD WATERS, CHANNEL DAMAGE AND DEBRIS

24. *Three major wildfires have burned 4,358 acres or about 32 percent of the Tonto Creek Watershed within the past ten years. These burned areas were seeded by aircraft and revegetation was highly successful.*

Three major wildfires have occurred within the Tonto Creek Watershed within the past ten years (fig. 12). In 1961, the Roberts Mesa Fire burned 2,543 acres in the southwestern part of the watershed where moderate topography prevails; and, later that same year, the Hatchery Fire burned 595 acres on the steep face of the Rim. In 1968, a third fire also named Hatchery Fire started below the Rim. This latter fire swept up the face of the Rim burning 1,220 acres within the watershed. Defying control by firefighters at the top, it continued north burning 3,694 acres on the Sitgreaves National Forest.

All three burns were reseeded by aircraft immediately after the fires were controlled. Revegetation was highly successful as evidenced by the burned area's grass cover and its withstanding of the September storm without appreciable on-site erosion from surface runoff.

Wildfires have long been looked upon unfavorably due to their effect upon increased runoff and erosion. To understand the effect that these three burns may have had on the subject flood is important to land managers today and to those in the future. The following paragraphs discuss this aspect of the flood.

RUNOFF

25. *All evidence points to more storm runoff and higher peak flows from burned areas in contrast to their preburn condition. This increase is attributed to decreased ground cover and a resulting decrease in infiltration capacity. Due to shallow rocky soils on part of the burned areas and slow infiltration rates on the remaining burned areas, the relative values of tree versus grass cover in providing soil water storage capacity was not a significant factor in the Labor Day flood on the Tonto Creek Watershed.*

Eight of the sampled watersheds were selected in pairs of close proximity for the purpose of comparing burned and unburned conditions under similar rainfall (fig. 5). Sample Watersheds 8 and 20 are located on the Sitgreaves National Forest just outside of the Tonto Creek Watershed boundary on top of the Rim in an area intensely burned by the 1968 Hatchery Fire. Sample Watershed 11 is located within the 1961 Hatchery Fire on the face of the Rim and Watershed 15 represents an area below the Rim burned by the 1961 Roberts Fire. Over 90 percent of the standing forest has been destroyed by past wildfires in each of these watersheds. Adjacent or nearby similar but unburned or only slightly burned watersheds (paired, burned watersheds shown in parenthesis) were Sample Watersheds 9 (8) and 10 (20), 12 (11) and 16 (15). Tables 7 and 8 summarize peak flow and surface runoff for these comparative watersheds. Figure 13 graphically summarizes peak flow in csm for three of the paired burned and unburned watersheds. Watershed locations are shown in figure 5.

In the three comparisons shown in figure 13, the burned watershed produced more runoff and higher peak flow in csm than did the unburned paired watershed as illustrated in the top one-half of the figure. However, definitive conclusions must not be drawn from this illustration alone. For a more meaningful comparison runoff was synthesized 1/ for the burned watersheds using the reconstructed rainfall and preburn vegetation and ground cover conditions as shown in Table 9. Comparison of the computed runoff and the synthesized runoff in the lower one-half of figure 13 shows that runoff on the burned watersheds would have been higher than on their unburned paired watershed even under preburn conditions. This relationship reflects the inherent higher runoff characteristics of the burned watersheds even in their preburned condition. The fact that they all would have exceeded their paired unburned watershed in peak flow (csm) in their preburn condition is due to coincidence. That is, it was not possible to select perfectly matched paired watersheds and it just happened that the burned watersheds sampled in each case characteristically would produce higher peak flows than their paired watershed under preburn conditions.

1/ Synthesized is used to identify runoff determined by using the SCS Runoff Curve Method as opposed to that computed from field measurements of high water marks using the Slope-Area Method.

Table 7 - Summary of peak flow and runoff for sampled watersheds including pre and postburn conditions.

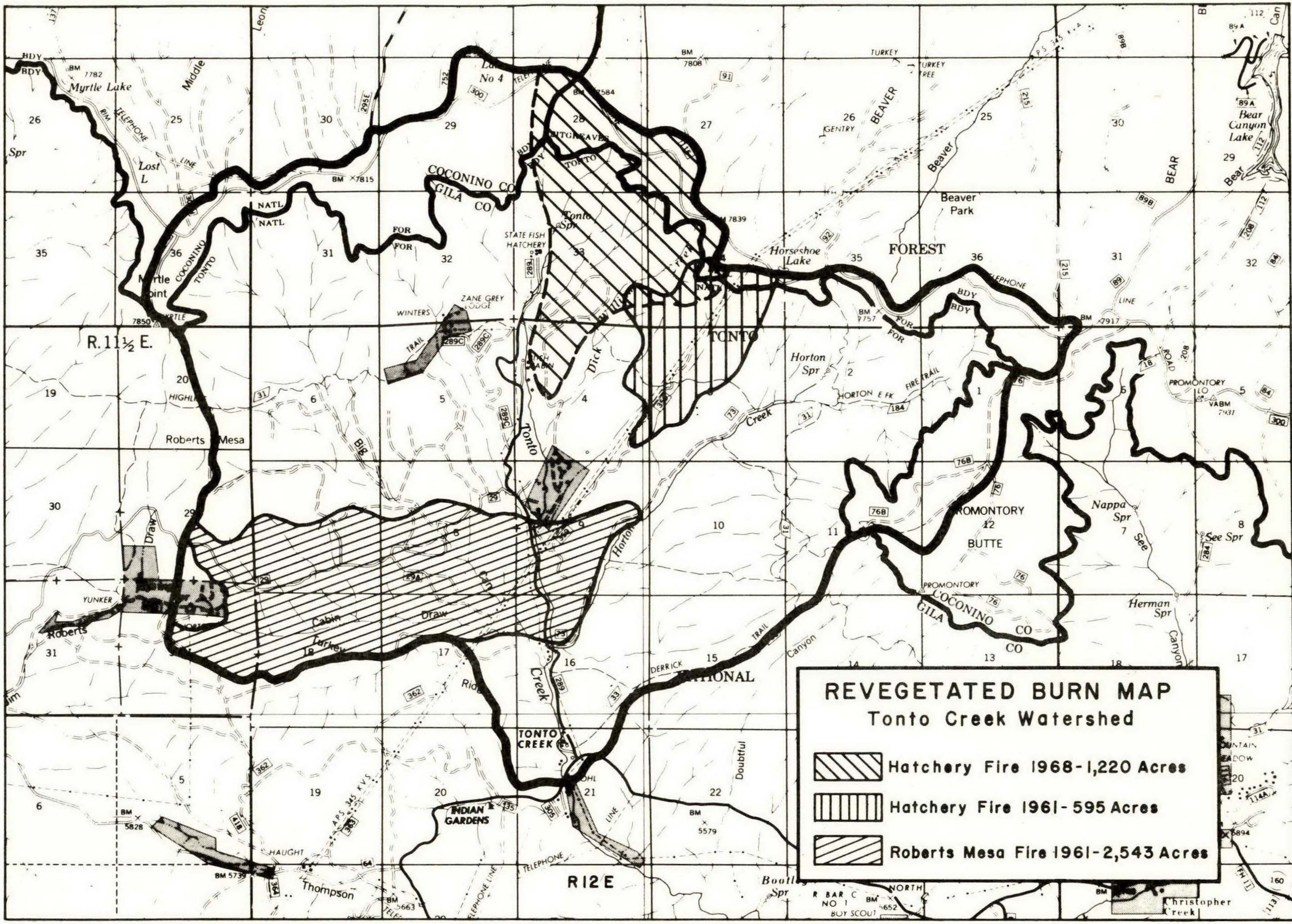
Watershed No.	Computed Peak Flow From High-Water Measurements		Peak Flows and Runoff Developed From Reconstructed Storm								
			Rainfall To Nearest 1/2 Inch	Synthesized Peak Flow				Synthesized On-Site Runoff			
				Exist. Cond.	Preburn Cond.	Change		Existing Cond.	Preburn Cond.	Change	
	cfs	csm	in	cfs	cfs		%	------area inches--------			%
1*	1/		(16)2/	820	748	72	10	12.28	10.44	1.84	18
3	107	2,488	12.0	105				6.87			
4	86	937	6.0	79				1.84			
5	91	577	5.0	97				1.44			
6	20	1,394	9.0	22				3.98			
7	115	581	5.0	115				1.23			
8*	359	2,909	12.0	349	218	131	60	6.87	3.71	3.16	85
9	242	2,279	14.5	243				5.40			
10	343	1,868	13.0	338				4.36			
11*	297	1,953	9.5	299	238	61	26	4.49	3.34	1.15	34
12	329	1,303	8.0	320					3.22		
13	128	4,354	17.0	120				11.36			
14	1,081	1,032	8.5	1,049				2.22			
15*	376	3,540	14.0	382	336	46	14	10.81	8.63	2.18	25
16	259	1,805	9.5	255				4.75			
17	1,626	477	5.0	1,561				.98			
18	2,540	2,241	11.5	2,575				5.84			
19	270	1,325	7.5	269				3.25			
20*	117	1,568	8.0	117	54	63	1.17	3.56	1.44	2.12	1.47
22*			(12.0)	2,255	1,972	283	14	7.02	5.79	1.23	21
23*		4,331	16	1,322	1,210	112	9	11.48	9.90	1.58	16
24*		4,198	16	640	561	79	14	12.60	9.90	2.70	27
Tonto Cr.	28,000	1,307	(8.0)	24,600	23,800	800	3	2.91	2.79	0.12	4
25 Big Canyon			(6.8)	6,443	6,034	409	7	2.37	2.18	.19	9
26 Upper Tonto			(7.7)	7,871	7,361	510	7	2.79	2.58	.21	8
27 Horton			(9.3)	11,823	11,823	0		3.45	3.45	0	

1/ Not a reliable measurement - estimate that flow exceeded all others observed in csm
2/ Rainfall from isohyetal map - not computed
* Burned watersheds

Table 8 - Comparative ground cover for burned and unburned paired sample watersheds for pre and postburn conditions.

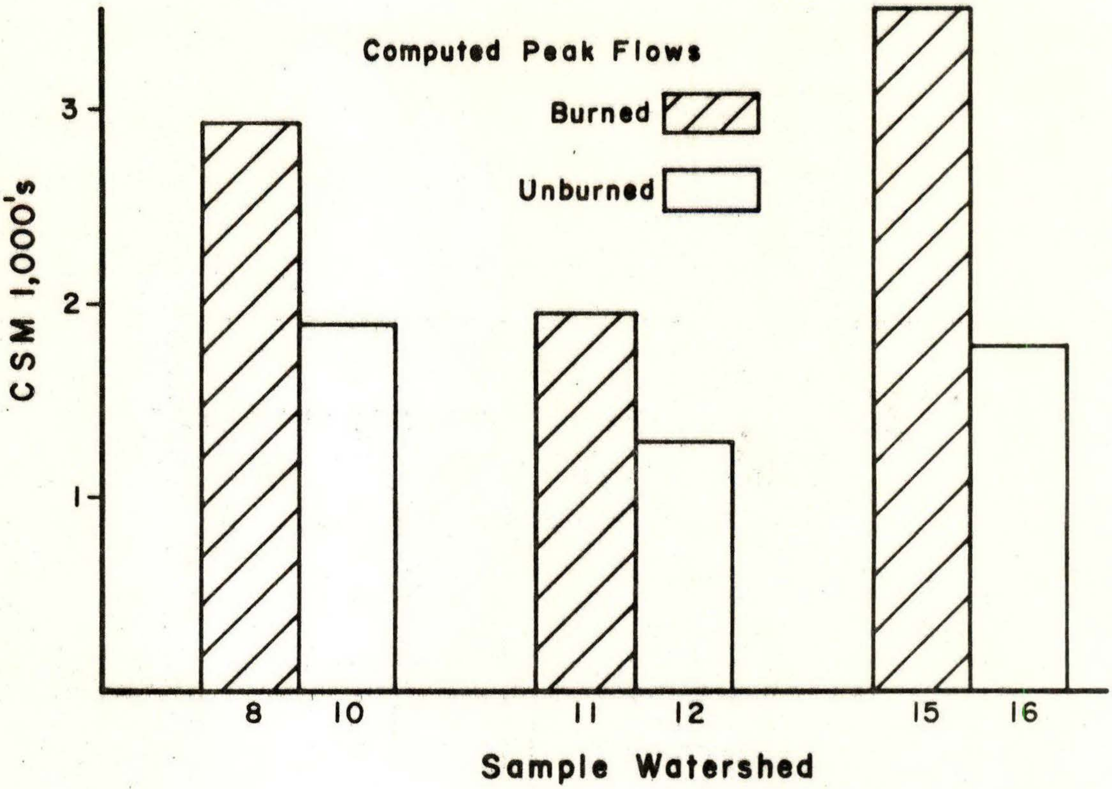
Watershed	Condition	Ground Cover Components In Percent 1/			
		Understory Plants	Litter	Rock	Bare Soil
8 & 20	Burned	30	30	15	25
8 & 20	Preburn	5	80	5	10
9 & 10	Unburned	5	80	5	10
11	Burned	25	35	30	10
11	Preburned	15	50	30	5
12	Unburned	15	50	30	5
15 2/	Burned	15	30	Trace	55
15 3/	Burned	40	30	Trace	30
15	Preburn	5	50	Trace	45
16	Unburned	Trace	40	20	40

1/ To nearest 5 percent
2/ Existing condition
3/ Potential under intensified management



REVEGETATED BURN MAP
Tonto Creek Watershed
Hatchery Fire 1968 - 1,220 Acres
Hatchery Fire 1961 - 595 Acres
Roberts Mesa Fire 1961 - 2,543 Acres
R.11½ E.
R12E
T.11 N.
Myrtle Lake
Roberts Mesa
COCONINO CO
GILA CO
STATE FISH HATCHERY
ZANE GREY LODGE
Horseshoe Lake
Beaver Park
FOREST
NATIONAL
TONTO
PROMONTORY BUTTE
Horton Spr
Nappa Spr
See Spr
Herman Spr
Bear Canyon Lake
TONTO CREEK
INDIAN GARDENS
Thompson
Christopher Creek

Figure 12



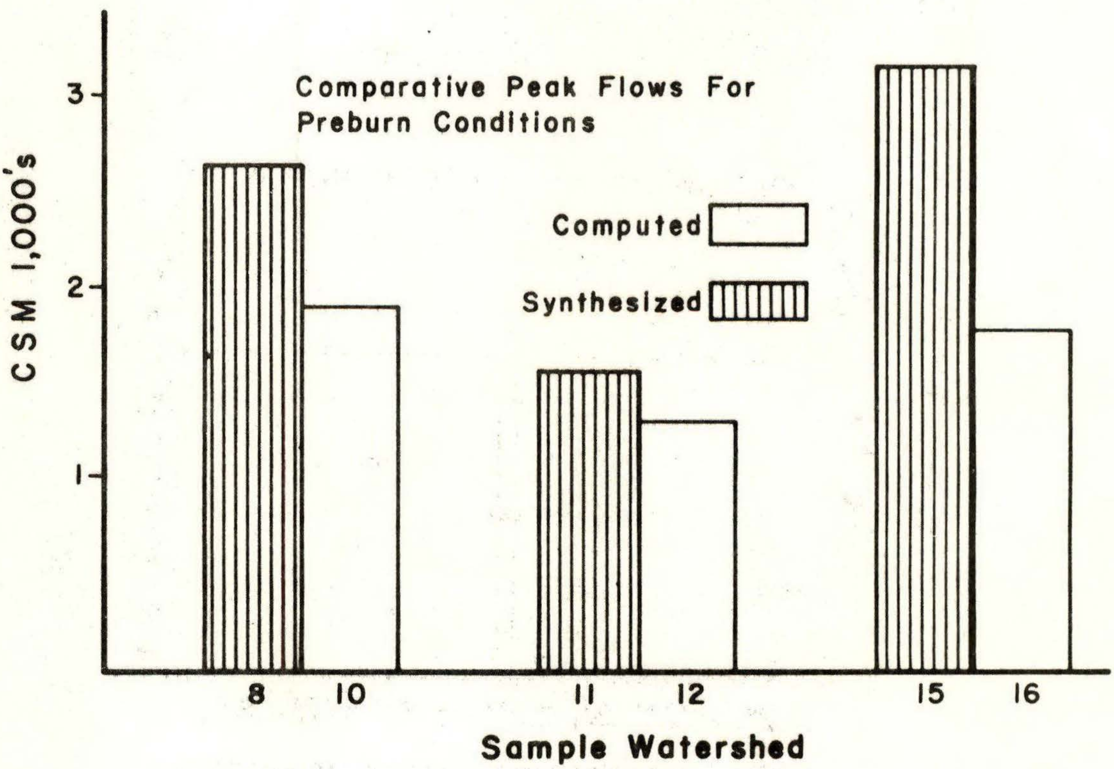
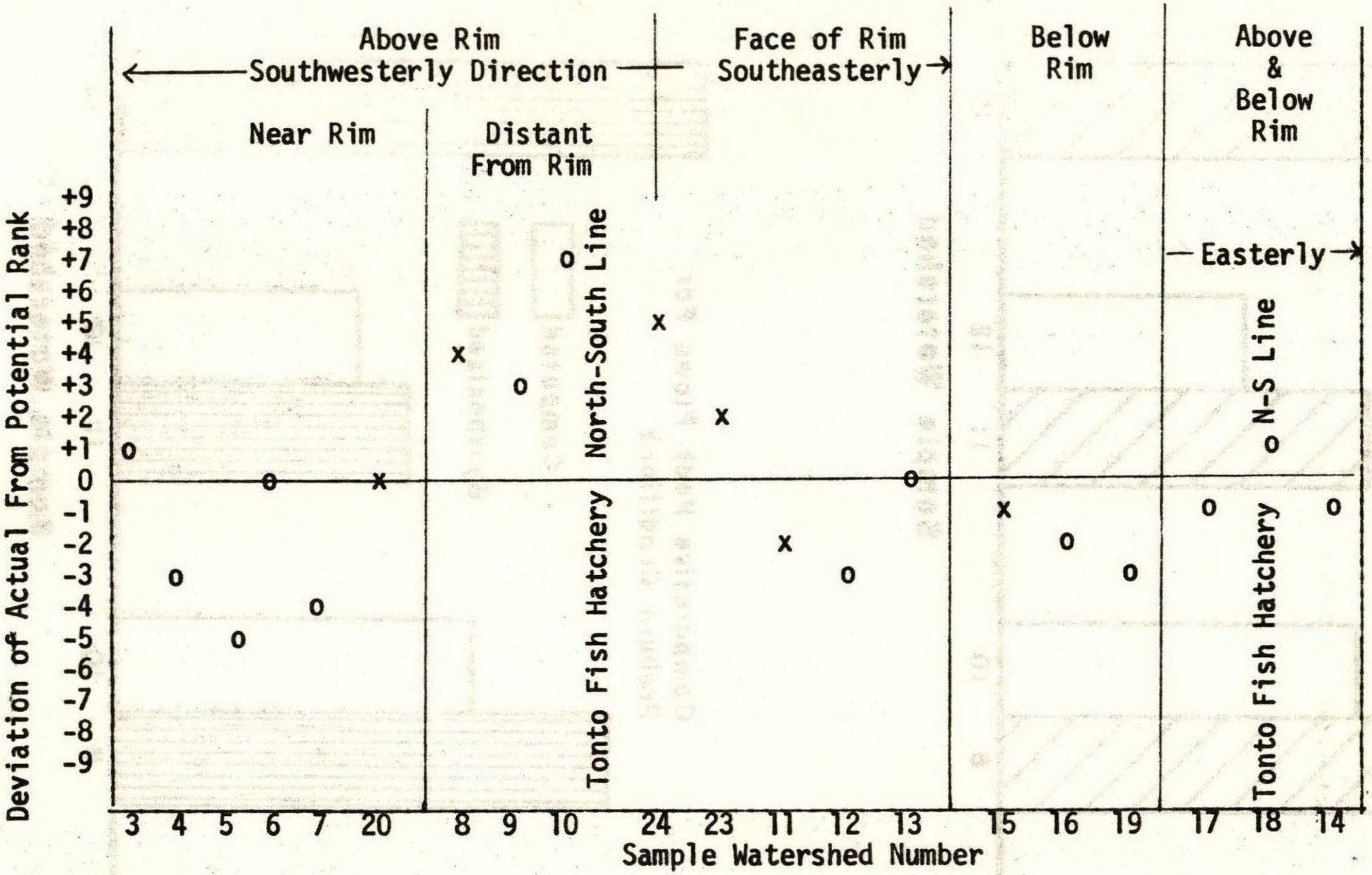


Fig. 13. Peak flows for burned and unburned paired watersheds within the Tonto Creek and adjacent areas.

Figure 14 - Deviation of Measured Peak Flows from Potential Rank



Interpretation:

The Rim area above and a short distance both east and west of the Tonto Fish Hatchery received higher rainfall than any other location.

Note: Potential ranking is based upon uniformly distributed rainfall.

X = Burned watersheds.

Note that Sample Watersheds 20 and 9 were omitted from figure 13. This was done because these two sampled watersheds were more widely separated in distance and the amount of rainfall which fell on Watershed 9 has been calculated to be nearly twice that which fell on Watershed 20. Watershed 20 is the only burned watershed sampled which had a lower peak flow than its paired unburned watershed (both 9 and 10). This is attributed to the great difference in rainfall and demonstrates the reason for the previous statement which suggests that definitive conclusions cannot be drawn from the basic field data alone.

The sample watersheds were ranked for potential peak flows in cfs assuming equal amounts of rainfall fell on each. They were ranked also for computed peak flows from high water marks for the purpose of comparison. A comparison is made for the paired sample watersheds in figure 14. In comparing peak flows in cfs size of watershed is critical, but comparative ranking, graphically shown in figure 14, demonstrates the anomalies or deviations from potential rank due to non-uniform amounts of rainfall which fell in the storm under study.

Any standard method of synthesizing runoff and peak flows for pre- and post-burn conditions will show more runoff under the burned condition and particularly so where ground cover and protective litter is less in relation to its unburned condition as it was in each burned watershed sampled.

26. *Attributing more runoff to burned as contrasted to unburned areas in general is supported by well documented research.*

There is ample research which demonstrates the relative effects of forest stands versus non-forested conditions in relation to hydrologic functioning. As recently as 1970, Luna B. Leopold, a nationally recognized researcher, summarized experimental watershed research as follows:

> As experimental data accumulated, it became clear that interception losses in forests can be large, averaging 15 to 25 percent of the rainfall; that the infiltration capacity of forested land is greater than similar land under cultivation; that trees break the impact of raindrops and prevent packing of the soil surface; that the presence of litter also reduces impact, reduces velocity of overland flow, and hinders surface sealing of pores. The greatest floods, however, are associated with rain or snow on ground already wet, under which conditions the presence of forest cover will not prevent floods but retards erosion and debris flows. Also, it appears that the differences between forested and non-forested areas are numerous and complicated.

Research and observation have commonly shown that watersheds which have deep-rooted vegetation removed and replaced by shallow-rooted species increase their subsurface runoff. The increase is due to the unavailability to the shallow-rooted plants of the water in the soil below the root zone for transpiration. This phenomenon is in complete contrast to the previously described condition of less ground cover and a resulting reduction in infiltration which results in increase overland flow. In terms of flood potential, the shallow-rooted plants are not able to extract the deeper layer of soil water and hence are unable to develop subsurface storage space for rainfall as in the case of the deep-rooted vegetation. When prolonged rainfall occurs, the smaller amount of storage space near the surface of the soil is filled sooner and hence runoff begins sooner and is increased in total amount by the same amount of water stored in the soil between the levels of deep-rooted and shallow-rooted species. Where soils are sufficiently deep, wildfires have such an effect through their removal of the deeper rooted trees and the replacement of the trees by a transitional stand of shallow-rooted grasses and forbs.

The phenomenon of shallow-rooted vs. deep-rooted conditions has revelance to Sampled Watersheds 8, 20, 9, and 10 on top of the Rim where soils are deep and moderately permeable. Here the unburned Watersheds 9 and 10 had more capacity to store rainfall. Note, however, that these watersheds are outside the Tonto Creek Watershed.

On the face of the Rim, except in isolated pockets, soils are rocky, moderately permeable, and shallow and were filled to saturation early in the storm regardless of their kind of vegetative cover. In the area of the Roberts Burn in the lower portion of the watershed, infiltration capacity in Watersheds 15 and 16 was the sole determinant of runoff. These watersheds have soils which are highly impermeable and were unable to reach saturation below 18 inches even under the conditions that prevailed from September 4 to 7.

Table 9 and figure 15 compare average rainfall, runoff and peak flow for different conditions for the Labor Day weekend storm over a wider area of central Arizona. The data shown are not intended to lead to definitive conclusions due to lack of comparability, but it is of interest to note that runoff in area inches and peak flow (csm) was higher in all cases where herbaceous species now replace trees or shrubs. The basis for the rainfall and runoff averages shown for Tonto Creek were derived from the sample watersheds and the data is based on computed peak flow only; whereas, the data from Forest Service Research Watersheds at Sierra Ancha and 3-Bar reflect actual gaged runoff and rainfall. It should be noted that, on the latter areas, rainfall is based on gaged amounts in the nearest gage and not watershed averages.

Table 9 - Rainfall and runoff for Tonto Creek and three study areas in central Arizona.

Location	Number of observa-tions	Total Sept. 3 to 7 Rainfall	Peak Flow CSM	Runoff Area Inches	Runoff As Percent of Rainfall
Tonto Creek					
Sample Watersheds					
Burned	6	12.6	3,104	8.30	66
Unburned	13	9.7	1,706	4.29	44
Tonto Creek Water-shed	1	8	1,307	2.91	36
Sierra Ancha					
Treated	2	10.30	162	1.96	19
Untreated	2	7.22	98	1.56	22
3-Bar					
Treated	3	7.17	41	.41	6
Untreated	1	8.04	37	.28	3
Beaver Creek					
Treated	5	5.36	800	Not available	-
Untreated	7		464	Not available	-

Table 10 - Antecedent Rainfall

Date	Station: Payson 12 NNE	Payson	Sierra Ancha	Tonto Cr. F.H.	Happy Jacks RS	Heber R.S.	Pleasant Valley
June	T	.06	.35	0	.07	.03	0
July	1.56	4.10	1.12	3.71	2.85	1.63	3.55
August	2.49	3.68	4.03	5.93	0.97	3.17	2.26
Sept. 1-4	.38	.25	.09	.25	.45	.06	.04
Total	4.43	8.09	5.59	9.89	4.34	4.89	5.85

Daily Rainfall August 1 - September 4 - Tonto Fish Hatchery

Day	Rainfall	Day	Rainfall	Day	Rainfall
1		13		25	
2		14	.75	26	.30
3		15	.43	27	
4	1.03	16		28	
5		17		29	
6		18	2.15	30	
7	.05	19	.23	31	
8	.04	20	.05	Sept.	
9	.05	21		1	
10		22	.20	2	
11	.21	23	.45	3	
12		24		4	.25

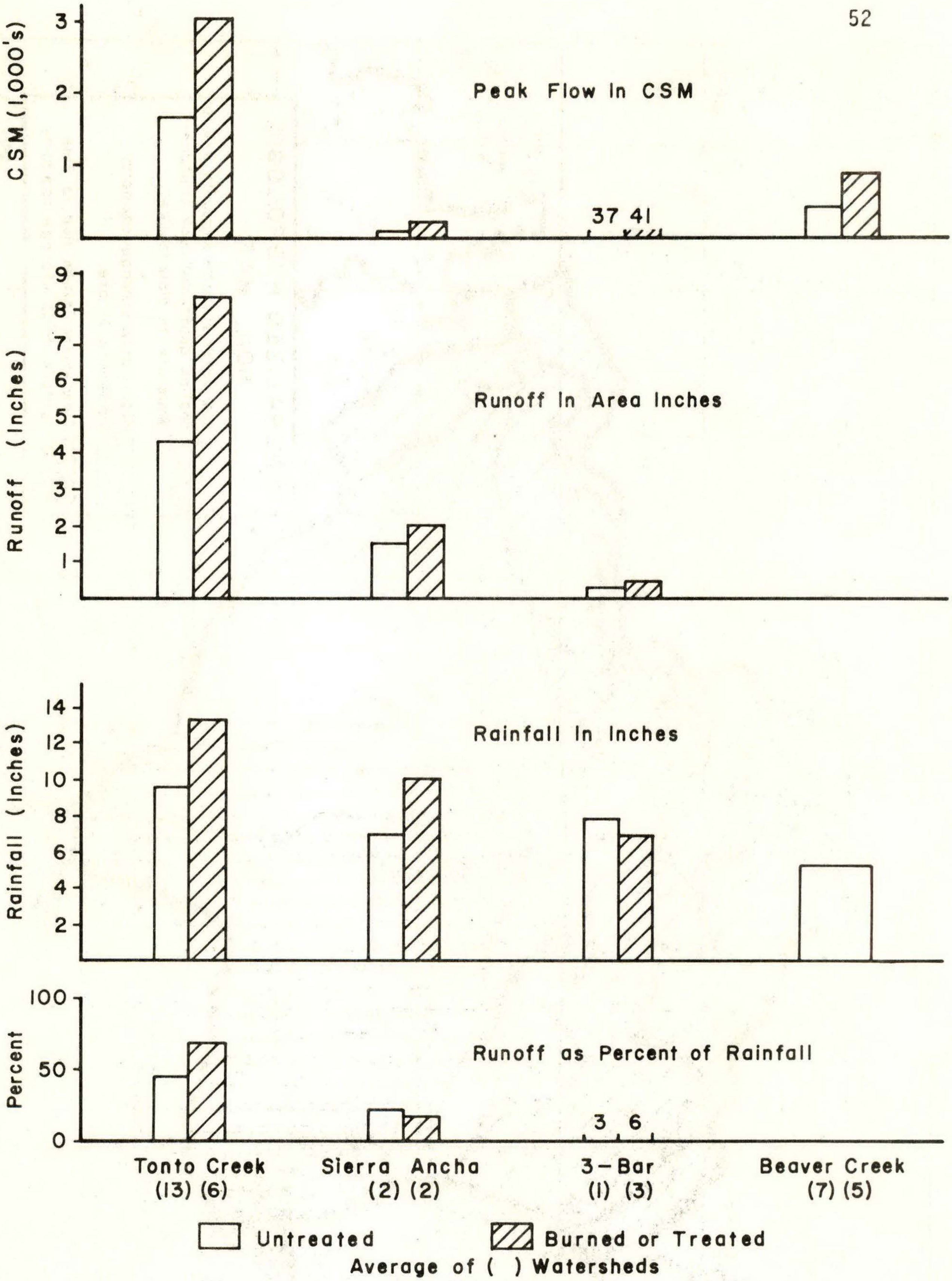


Fig. 15. Rainfall and runoff for Tonto Creek in relation to three study areas for September 3-7, 1971 .

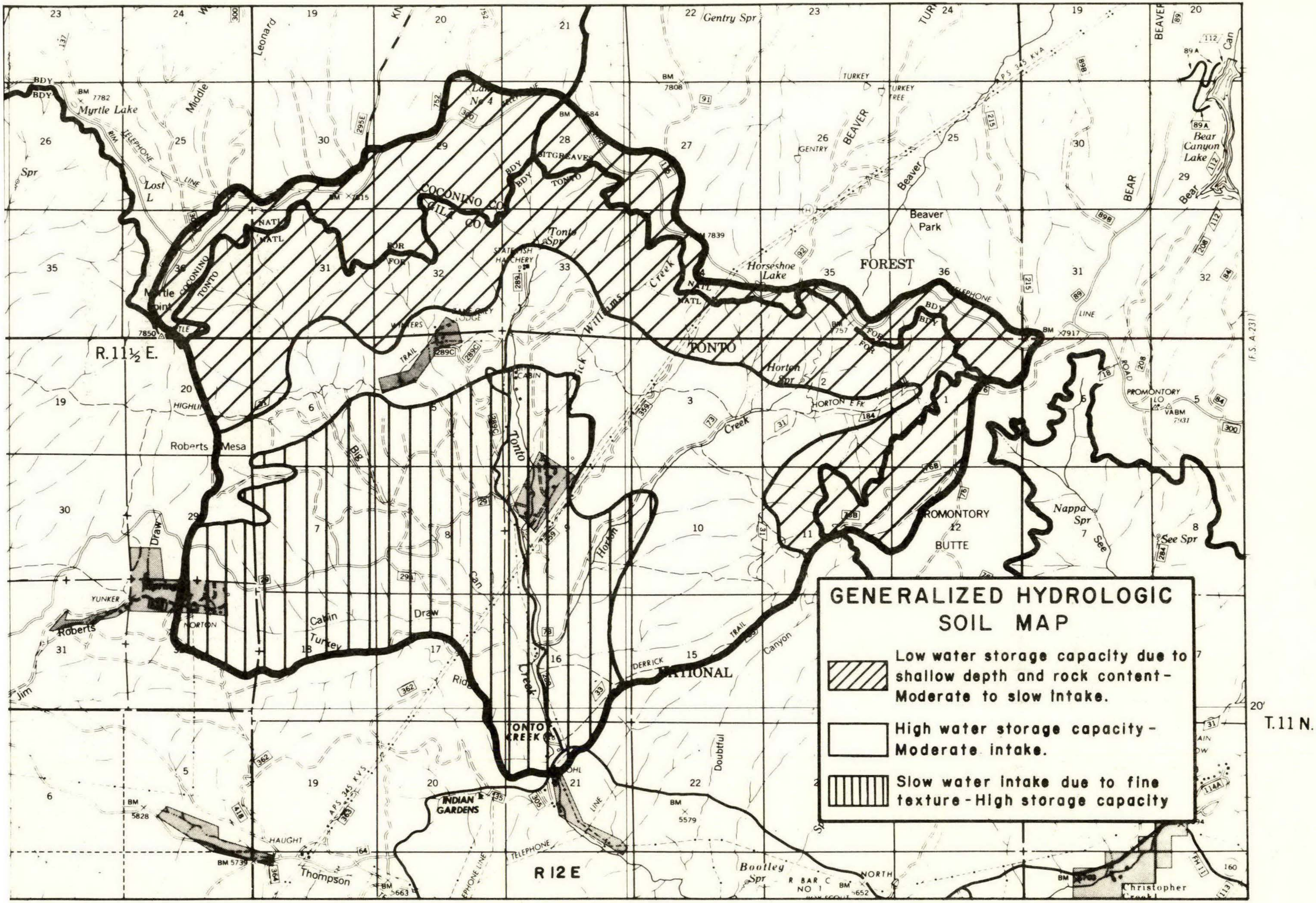

GENERALIZED HYDROLOGIC SOIL MAP
Low water storage capacity due to shallow depth and rock content - Moderate to slow intake.
High water storage capacity - Moderate intake.
Slow water intake due to fine texture - High storage capacity
R.11½ E.
R 12 E
T.11 N.
Myrtle Lake
Roberts Mesa
Beaver Park
Horseshoe Lake
Bear Canyon Lake
FOREST
TONTO
NATIONAL
COCONINO CO
GILA CO
INDIAN GARDENS
TONTO CREEK
Thompson
Christopher Creek
Gentry Spr
Tonto Spr
Horton Spr
Nappa Spr
See Spr
PROMONTORY BUTTE
PROMONTORY LO
Doubtful
Bootley Spr
Turkey
Cabin
Draw
Can
Ridge
Creek
Tonto
Horton
Williams
Big
Beaver
BEAR
Yunker
Roberts
Haught
Derrick
Trail
Canyon
Telephone Line
APS 345 KVS
Highline
Lost L
Spr

Figure 16

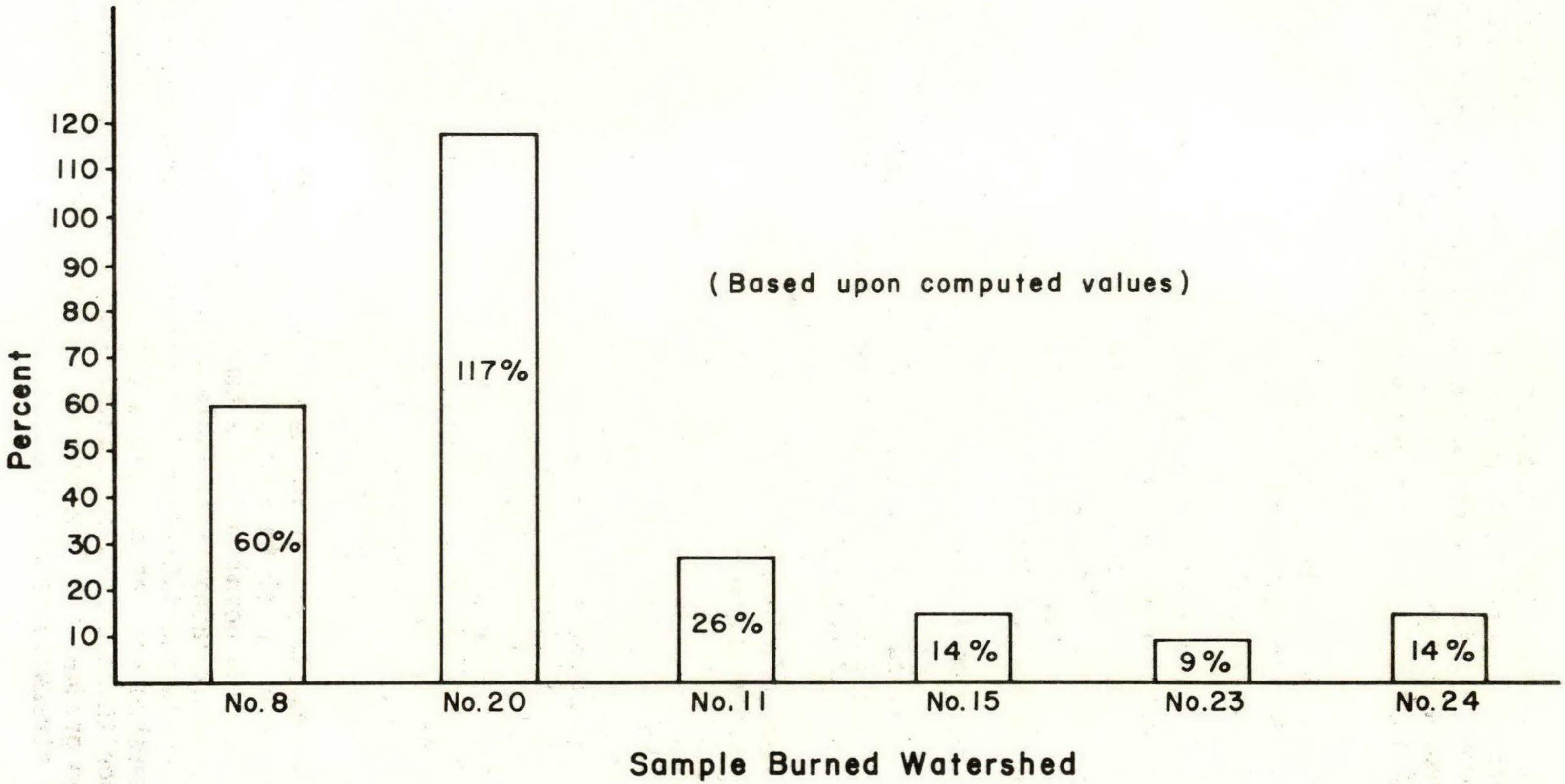


Fig. 17. Percent increase in peak flow attributed to burned condition.

Closer inspection of the rainfall and runoff records for the cluster of Workman Creek Study Watersheds at Sierra Ancha further suggests that more runoff occurred on watersheds where the timber had been removed or appreciably reduced in stand density. Runoff as a percent of rainfall is shown for each of the three mixed conifer watersheds below:

North Fork Workman Creek (Cleared)	21 percent
South Fork Workman Creek (Heavy Cut)	17 percent
Middle Fork (Control-Natural condition)	12 percent

However, further study and analysis would be required to demonstrate statistically that the treated watersheds did, in fact, yield more storm runoff in proportion to severity of treatment than they would have yielded in their pretreatment condition. Further analyses will be made and reported on by the Rocky Mountain Forest and Range Experimental Station for several central Arizona study watersheds.

27. *Approximately five inches of storm rainfall were stored in the soils of the Tonto Creek Watershed. On 34 percent of the watershed, storage capacity was not fully utilized due to the inherent low infiltration capacity of the soils and the high rainfall intensity.*

The amount of storage capacity for water in the soil is a critical factor for those areas having moderate to high infiltration and percolation rates (fig. 16). When soil moisture has dried to near the wilting point, the most permeable soils covering 48 percent of the Tonto Creek Watershed have the capacity to store approximately 4,500 acre feet of water, the equivalent of 8.3 inches of rainfall over the same area. The remaining 52 percent of the study watershed has soils with low intake rates for water; and, as a result, the approximately 3,200 acre feet (5 inches) of storage capacity is essentially unattainable during periods of intense rainfall. On 34 percent of the watershed, the Labor Day storm did not wet the soil below the 18-inch depth due to low infiltration rates. The storage capacity referred to in both cases includes both short term detention and long term retention storage.

Eighty-four percent of the Labor Day weekend storm rainfall could have been stored in the soil assuming (1) that soil moisture was near the wilting point when the Labor Day storm began (it was not--see antecedent rainfall in table 10), (2) that all rainfall which fell was below the intake rate of the least permeable soil in the study watershed (it was not), and (3) rainfall was 8 inches evenly distributed. Under these conditions, approximately 4,500 acre feet of water would have been gradually released from temporary storage as ground water recharge and streamflow and 3,100 acre feet would have been retained for use by

vegetation. Of course as noted, this simplified theoretical example was not the case, but these calculations serve to demonstrate the importance of soil-moisture-storage on the watershed. In many forest and brushland areas, vegetation management can be used to manipulate soil moisture storage capacity to either provide increased flows during low flow and formerly no flow periods or to provide storage space for rainfall which might otherwise contribute to flooding.

Other aspects of interest in discussing the storage of rainfall in the soil mantle are the amount, timing, and relative intensity of rainfall. Using the developed rainfall distribution curve (fig. 4) and a total rainfall of 8 inches assumed to be evenly distributed over the study watershed, approximately 3,600 acre feet (3.1 inches) of rainfall fell prior to the intense burst of rainfall on the afternoon of September 5 and 5,200 acre feet (4.6 inches) fell during the intense period. Much of the latter amount could not infiltrate into the soil due to already saturated conditions or slow intake rates.

These volume amounts of rainfall seem meaningful when considering that by other methods runoff for the Tonto Creek Watershed for the Labor Day storm is estimated at approximately 3,322 acre feet (2.9 inches). This amounts to 36 percent of the total storm rainfall leaving the watershed as runoff. In summary, the evidence strongly indicates that approximately 5 inches out of 8 inches of average storm rainfall were stored in the soils on the watershed; and, in this particular watershed, very little, if any, additional storage could have been provided through alternative management programs.

28. *Within the Tonto Creek Watershed, peak flows from small tributary watershed may have been increased by as much as 26 percent due to burned conditions; but the total affect on the peak in Tonto Creek at Kohl's Ranch was an increase of only 3 percent. This small increase in peak flow from the burned areas is attributed to successful revegetation and the widespread distribution of the burns.*

From the preceding discussion, it is concluded that the Tonto Creek Watershed absorbed large amounts of rainfall. The absence of the former stands of trees killed by wildfire did not greatly affect the total volume of rainfall stored on the watershed from the September 4-6 storm due to the shallow soil depths and slow infiltration rates of the predominate soils within the burned areas and the occurrence of a large volume of rainfall prior to the intense rainfall period. The greater amount of bare soil within the burns did result in reduced infiltration and more runoff moving rapidly over the ground's surface in ratio to that which would have been detained in moving through the soil and litter under the preburn condition. As a result, synthetic runoff determinations show appreciably higher peak flows from the burned areas as exhibited by Watershed 11 (tab. 7 and fig. 17) with

an increase of 34 percent above its preburn volume of runoff and 26 percent above it preburn peak flow. However, relatively small increases in peak flow are attributed to the burned areas for the larger Tonto Creek Watershed above Kohl's Ranch (tab. 7). The synthesized peak flow at Kohl's Ranch, due to the burns' effect, is only 3 percent more than would have resulted had the burns been in their preburn condition. This small effect is due to the relative size of the burned area in relation to the larger watershed and the widely separated location of the individual burned areas which prevented synchronization of their contributed peaks.

Had the entire Tonto Creek Watershed been recently burned and without protective vegetation, the runoff and erosion which could have occurred on September 5 would have dwarfed to insignificance that which actually did occur. For although the burned areas contributed more runoff and higher peak flows, their limited acreage and the stabilizing benefits of the restored vegetation held on-slope erosion to insignificance and peak flow to a possibly slight increase on Tonto Creek at Kohl's Ranch.

CHANNEL DAMAGE AND DEBRIS

29. *Channel damage was severe on both burned and unburned watersheds.*

Overall comparative observation between channels draining burned and unburned watersheds show no detectable difference in relative stream channel damage. Horton Creek and See Canyon in Upper Christopher Creek, neither of which were influenced by recent wildfires, provide adequate evidence of this fact. There was debris available in both cases for the development of debris dams with their attendant surges of escaping water and diverted flows. In some areas debris flows 1/ contributed to the increasing magnitude of downstream channel damages.

30. *Debris flows occurred at several locations on the face of the Rim and channel damage below debris flows was greater than above.*

Debris flows were noted in several locations on the face of the Rim. Below the point of entrance of each debris flow into the main channel damage immediately downstream was contrastingly greater than above. This is not to say that all channel damage was related to debris flows. Severe channel damage was widespread even where there were no debris flows.

1/ Debris flow is a term defining all types of rapid flowage of debris of all kinds. A more specific term is debris avalanche which implies sudden movement downslope of the soil mantle on steep slopes caused by its complete saturation through protracted heavy rains.

31. *Three large debris flows on Upper Dick Williams Creek deposited approximately 14,000 cubic yards of material in the stream channel causing severe damage downstream. Adjacent and similar burned watersheds show comparatively minor channel damage although their peak flows were very high over 4,000 csm (cubic feet per second per square mile.)*

The most damaging debris flows occurred in Upper Dick Williams Creek. Here three large debris flows deposited approximately 14,000 cubic yards of rock and soil (not including trees) at practically the same location in the stream channel resulting in a large debris dam. From this point downstream, channel destruction was more severe than for any other drainage observed. Note in figure 18 and photos 16 and 17 that although Watersheds 23 and 24, adjacent to Upper Dick Williams Creek, produced peak flows of over 4,000 csm comparatively little channel damage occurred.

32. *All debris flows observed were within burned areas but other factors rule out any definitive conclusion that the debris flows were fire caused.*

All debris flows observed occurred in the paths in which similar flows had taken place centuries before (compare figs. 18 and 19.) Over the years colluvial materials and deep weathering had loaded the paths with new material similar to that in which a snow avalanche path periodically loads and unloads by avalanching. In the case of the debris flows, trees and other long lived vegetation had grown on the paths masking their potential danger and holding them in place against all storms untill this one of unprecendented magnitude occurred.

Five major debris flows have been identified on the face of the rim in the burned areas of Tonto Creek (fig. 18). None of similar magnitude have been observed or reported along adjacent unburned sections of the Rim. However, this observation alone is insufficient evidence for conclusively stating that the debris flows were fire caused. Their cause is also related to the following:

1. The debris flows occurred where rainfall was heaviest.

2. The debris flows occurred where geologic factors were most conducive to mass movement of the soil-rock mantle. These factors include (a) the large amount of accumulated debris, (b) the slopes of 80 percent and above on which it lay, and (c) a bare rock area which lies above and from which nearly all rainfall was shed.

Also, the debris flows in the burned area may be more visual and therefore the only ones observed for the following reasons:

1. The debris flows were observed in an area studied intensively through the use of post-flood aerial photography.

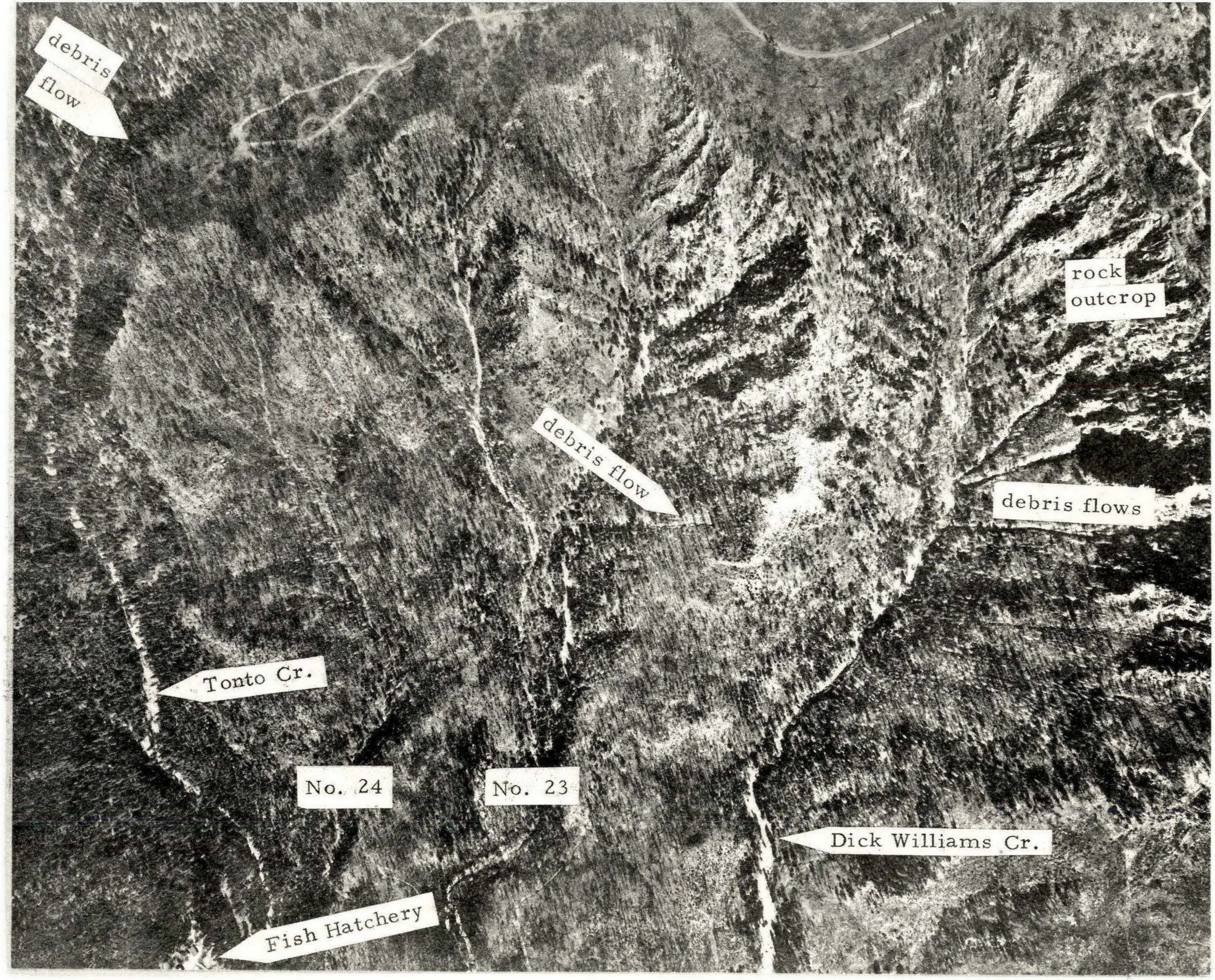


Figure - 18 Aerial photograph of Upper Dick Williams Cr. after September 5, 1970 flood.

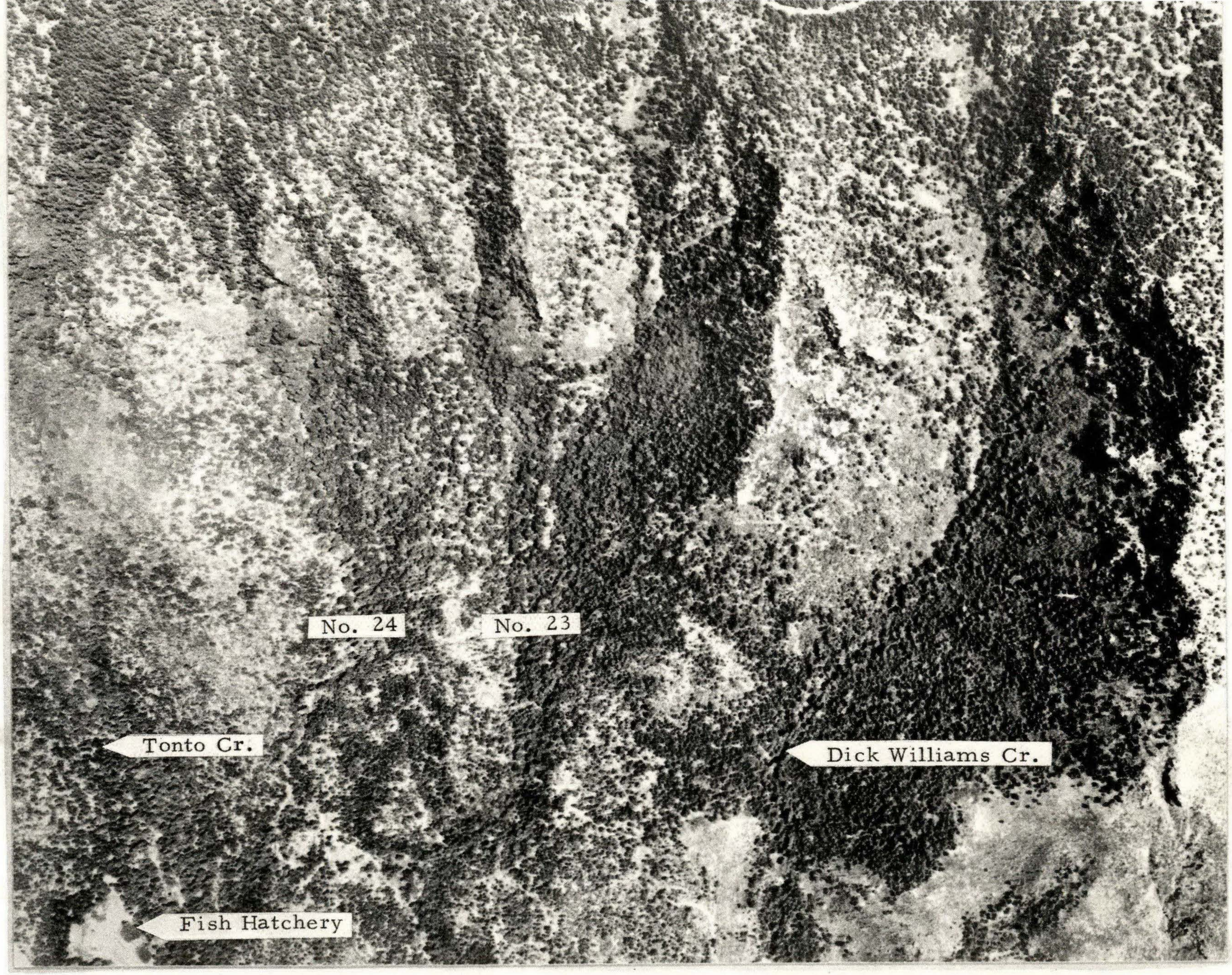


Figure - 19 Aerial photograph of Upper Dick Williams Cr. before 1968 Hatchery Fire.

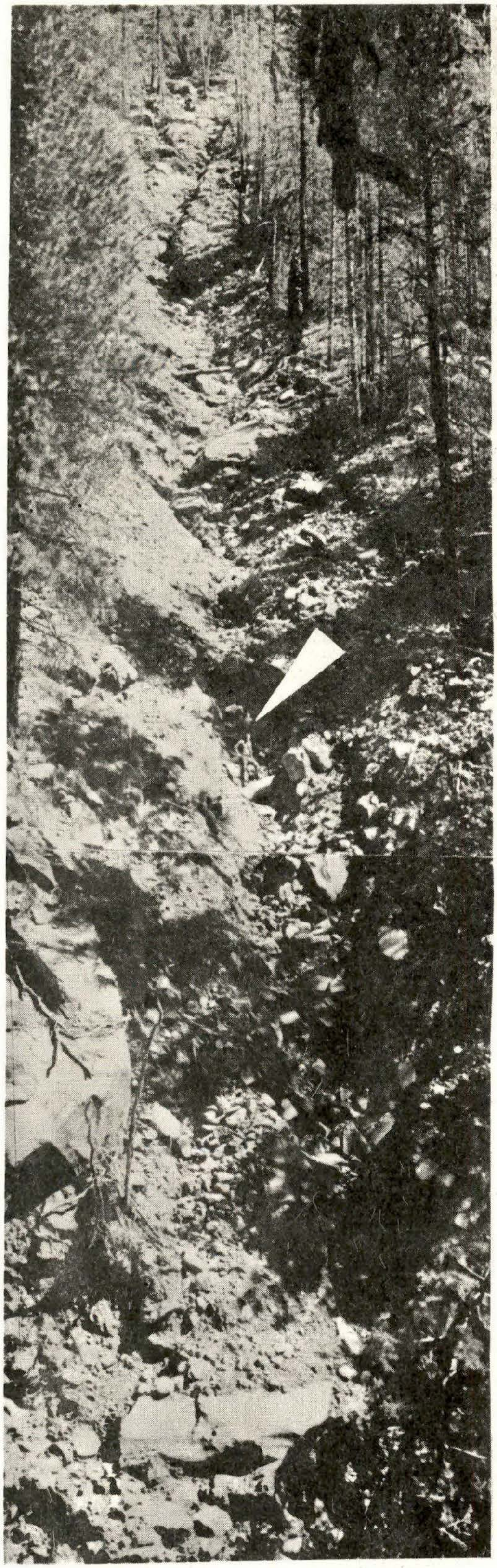
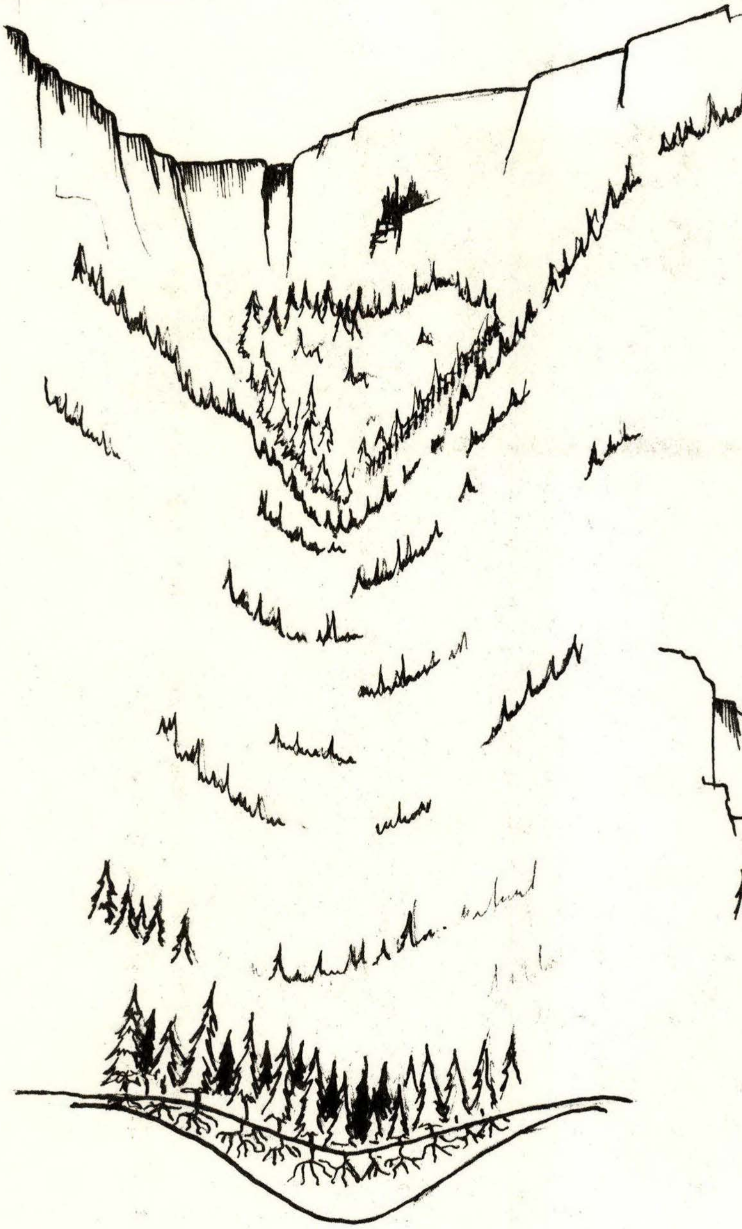
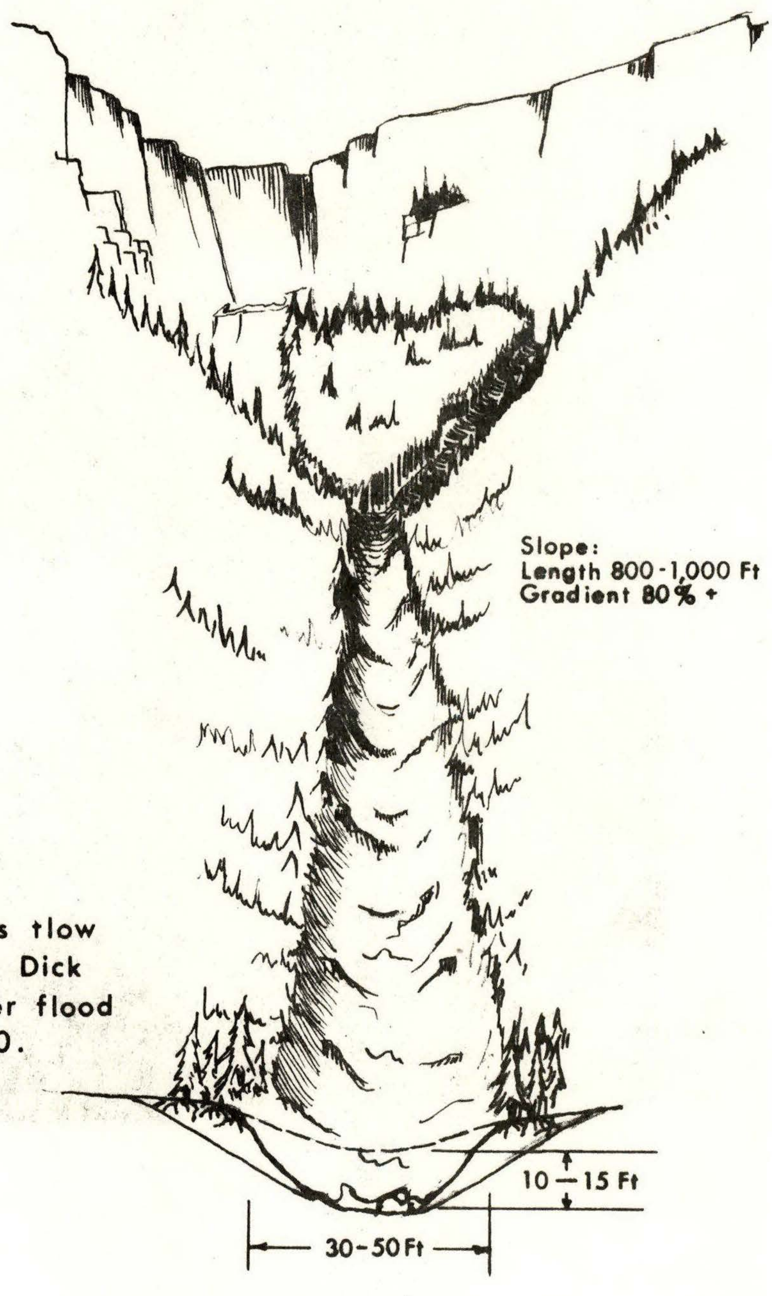


Photo 15 - The most southerly of three major debris flows occurring in Upper Dick Williams Creek. These mass movements extend from the stream channel to the base of the rock outcrops near top of Rim. Note man at point of marker.



Before Flood



After Flood

Figure 20. Illustration of debris flow dimensions on Upper Dick Williams Creek after flood of September 5, 1970.

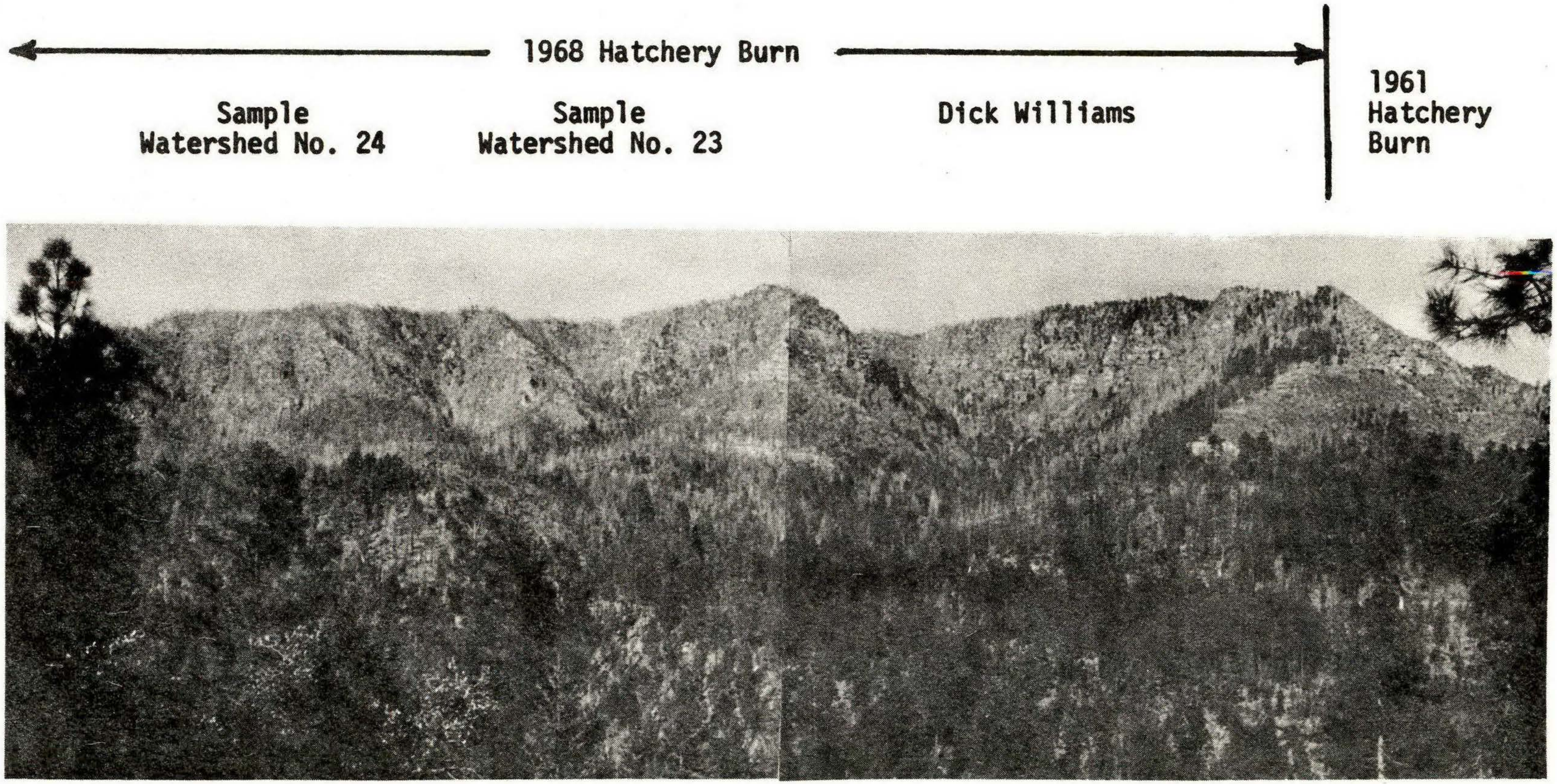


PhotO 16 - View of Mogollon Rim showing locations of Sample Watershed Nos. 23 and 24 and Dick Williams in relationship to 1968 and 1961 Hatchery Burns.

Sample Watershed No. 23 - 195 acres

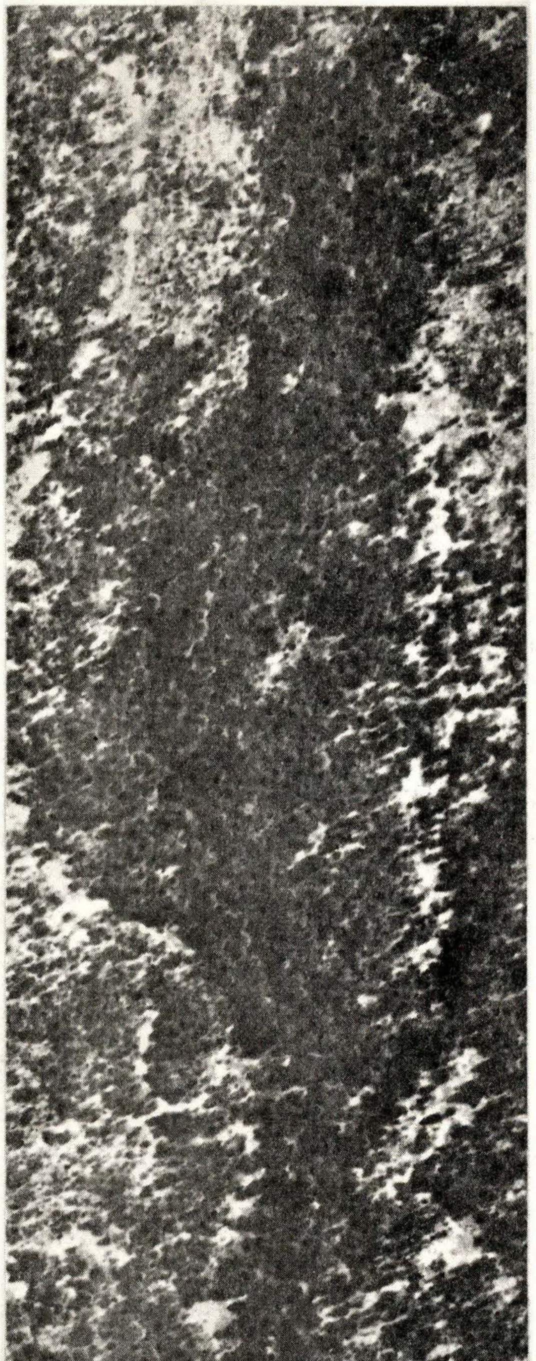
Sample Watershed No. 24 - 98 acres

Photo 17 - Channels leading from Sample Watershed Nos. 23 and 24 were only slightly damaged as compared to Dick Williams, although they were similarly burned by the 1968 Hatchery Fire.

Severe channel damage begins where the most northerly of three major debris flows enters the channel. Note debris flow enters on the right leaving a large debris pile on the left. There are 68 acres in Dick Williams Creek above this point.

Looking downstream, the debris was deposited to a depth of 30 feet through which a channel was later cut.

Photo 18 - Channel damage caused by debris flows in Upper Dick Williams Creek.



Before Flood

After Flood

Figure - 21 Aerial view of stream channel damage in Upper Dick Williams Creek before and after September 5, 1970 flood.

2. The debris flows were observed in an area where the absence of trees makes them more visible.

The sequence of events that most likely lead to the debris flows resulted from the extremes which accompanied the Labor Day Weekend Storm. First, rainfall occurred in sufficient amounts to bring most of the soil and rock mantle above bedrock to field capacity. Second, early stages of streamflow were of a magnitude which resulted in downcutting which left banks and the toes of side-slopes undercut and unsupported. And finally, an intense burst of rainfall fell bringing all the soil and rock mantle above bedrock to saturation, adding thousands of tons of weight which had never existed before. The added weight of the water, the removal of supporting material below and the well lubricated interface between bedrock and the soil-rock mantle were the conditions which set into process the cataclysmic flow of debris into the drainage channel below. The extended duration of intense rainfall provided enough streamflow to transport the material down the steep stream channels.

To say the debris flows are fire caused one of two explanations must be accepted:

1. The first explanation is that the fire-killed trees resulted in a fully saturated rock and soil mantle below the upper horizons prior to or at least early in the Labor Day Weekend Storm period hence providing the lubrication and weight necessary for the occurrence of the debris flow which otherwise would not have existed.

2. The second explanation is that the binding effect of the tree and shrub roots was reduced through decaying action thus shearing under the heavy load, whereas live flexible roots would not have given way.

Neither of the two preceding explanations seem plausible in this particular case. This study indicates there was sufficient rainfall to saturate the deep troughs where the debris flows occurred regardless of the presence of deep-rooted vegetative cover and, the dead trees were killed by the 1968 Hatchery Fire which does not provide sufficient time for adequate root decomposition. Also, much of the vegetation on the slopes was Gambel Oak which is not killed by a single fire.

It follows that there is not sufficient evidence to conclusively state that the debris flows were or were not fire caused. To delve further into the cause offers academic challenge more than practical benefit.

It is inconceivable that the present policy of intensive fire protection and control in the Rim area will diminish. The present policy consists of taking every practical precaution to prevent wildfires, to aggressively control them once they do begin, to restore the burned areas with a protective vegetative cover as rapidly as possible, and to intensify management after vegetation is established.

There is no known program in any land management agency today which would intentionally remove native vegetation from slopes as steep as those found on the face of the Mogollon Rim in the vicinity of Myrtle and Promontory Points.

NATIONAL FOREST MANAGEMENT AND WATERSHED PROTECTION

Management of the Tonto Creek Watershed is coordinated under the Payson Ranger District Multiple Use Plan. Uses consist of timber harvesting, livestock grazing, and several types of outdoor recreation including hunting and fishing. Producing water of good quality has been an important consideration in all management decisions. Streamflow from Tonto Creek flows into Roosevelt Lake for use to generate electric power, irrigate lands in the Salt River Valley and provide for water oriented recreation. Prior to the September flood, Tonto Creek was one of the better known and more heavily used trout streams in the State. The heavy fishing use and related camping on Tonto Creek can be attributed to the scarcity of such streams in the Southwest and the close proximity of this stream to the population centers in and around Phoenix from which Kohl's Ranch can be reached by paved road in about a two-hour drive.

Two unique places of interest lying within the Tonto Creek Watershed which also add to its attraction are the Zane Grey Lodge on private land and the Tonto Creek Fish Hatchery under National Forest permit. The fish hatchery is operated by the Arizona Game and Fish Department. A large supply of low temperature water of good quality is essential for its operation. The damage to this facility by the September flood was disasterous. The pipeline which carried water from springs a short distance upstream was destroyed and the spring box was buried under 30 or more feet of rock and other debris. The estimated damage to the hatchery is $203,000. High value watersheds on National Forest lands such as that drainage area above the fish hatchery are given special consideration in making all related land management decisions.

Considerable work had been done prior to the flood on Tonto and Horton Creeks to improve the fishery. Most of this work consisted of constructing small obstructions in the streambed to create scour pools which provide cover and resting places for trout.

There are 50 acres of developed and undeveloped campground and picnic sites along Tonto Creek and 430 acres of State and private lands occupied with summer homes. Visitor day use, an index to recreation use, increased from 50,000 visitor days in 1965 to 80,000 in 1969. This heavy use increases the danger of man-caused fires particularly in the late dry spring months before the summer rains begin about the first of July.

Due to the potential fire danger and the high recreational value of the resources of Tonto Creek, supplemental measures for fire prevention, detection, and rapid initial attack are provided during the critical fire period. A Rim Patrol travels the length of Tonto Creek twice daily during the fire season. During daylight hours, Diamond Point, Baker Butte and Promontory Lookouts provide constant surveillance. During extreme conditions, a 25 man Southwest Fire Fighter (SWFF) crew is stationed at Indian Gardens, the area is placed under periodic and frequent surveillance from aircraft and when fire hazard conditions warrant restrictions on public uses and closure orders are put into effect. Fire suppression is facilitated by a maintained road system of 25 miles (fig. 22).

The Forest Service policy has been to take immediate action to restore favorable watershed conditions after the major fires were controlled. Wildfires leave burned areas which are extremely vulnerable to high intensity rainstorms prior to the re-establishment of protective vegetation. For example, the Hatchery Fire of 1968 occurred around the first of July just prior to the usual arrival of summer thunderstorms. It burned 1,220 acres within the watershed. On 65 percent of the burned area, this fire burned extremely hot resulting in 70 percent tree mortality and consumption of over 95 percent of the protective ground cover. A seed mixture of weeping lovegrass, clover and ryegrass was applied immediately from aircraft. Photos 19 and 20 show the successful establishment of protective cover which will serve as a "first aid" treatment until other natural species become established.

During 1962 and 1963, the Myrtle Point Timber Sale was harvested. This sale consisted of 3,778 acres within the study watershed. In addition, salvage sales have been made on the burned areas. Pulpwood harvests started in 1963 and a total of 1,220 acres have been cut most of which is within the Myrtle Point Timber Sale Area.

All timber harvesting carried out to date within the Tonto Creek Watershed has been for one of three purposes: (1) to remove mature, over mature or high risk trees due to such causes as insect attacks, diseases and lightning strikes, (2) to remove competing pulp sized tree growth to release potential harvest trees for increased rates and quality of growth, and (3) to salvage timber killed by wildfire which would otherwise be an economic loss and a potential source for an insect outbreak of epidemic proportions. Logging roads are drained and reseeded upon completion of their use. There are 58 miles of such roads within the Tonto Creek Watershed. The locations of past timber sales are shown in figure 23.

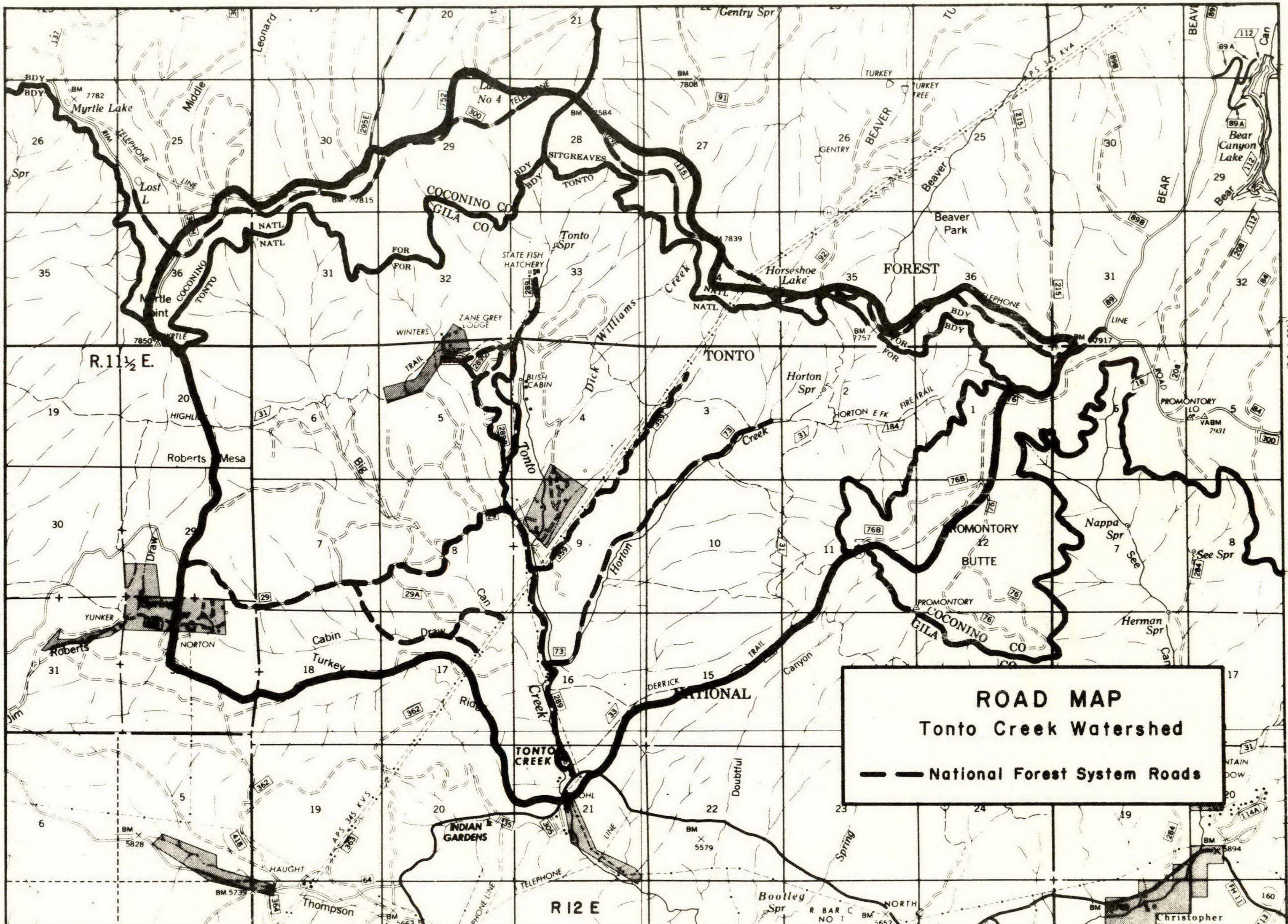

ROAD MAP
Tonto Creek Watershed
National Forest System Roads

Figure 22

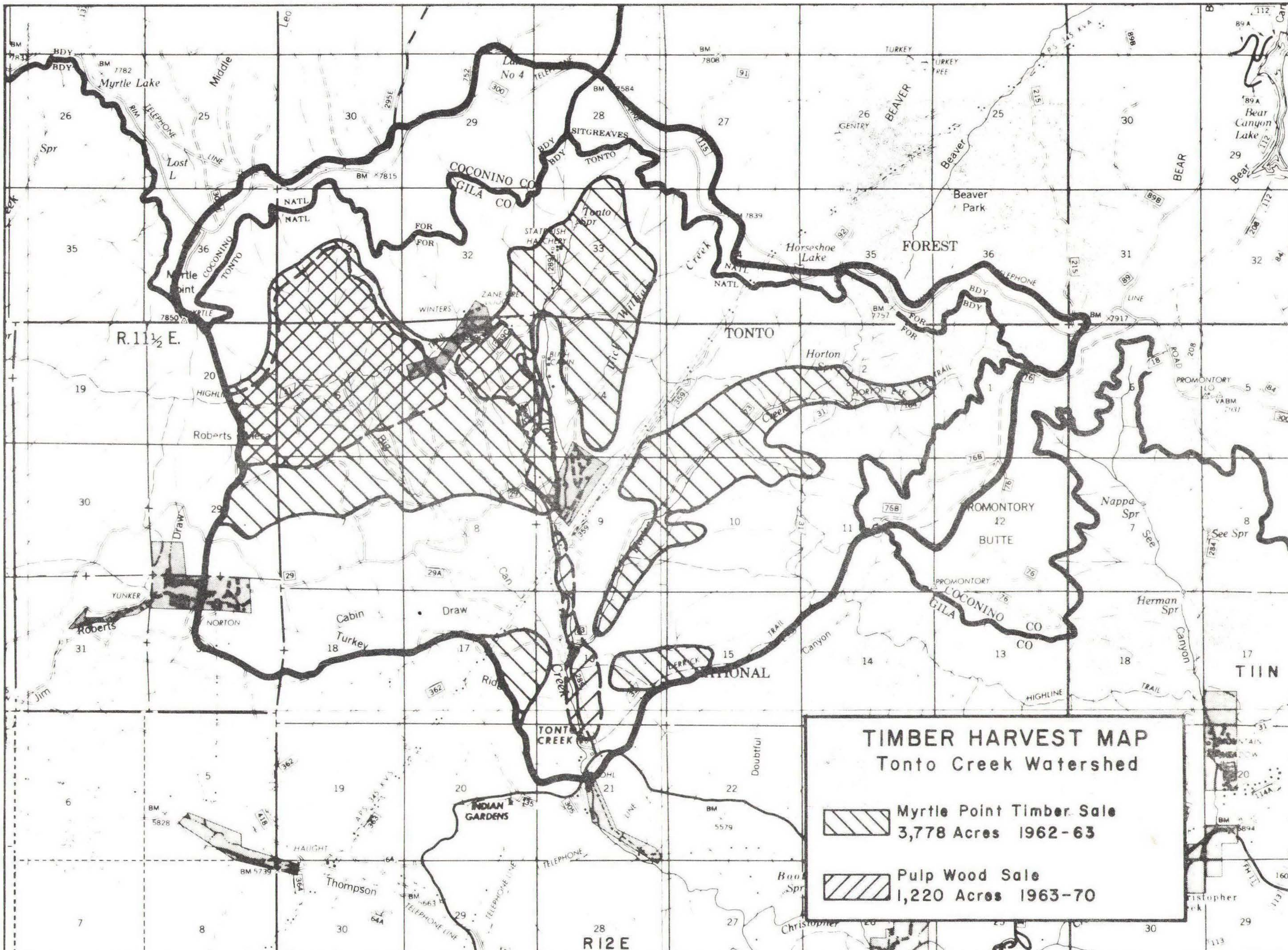

TIMBER HARVEST MAP
Tonto Creek Watershed
Myrtle Point Timber Sale
3,778 Acres 1962-63
Pulp Wood Sale
1,220 Acres 1963-70
R.11½ E.
R12E
T11N
COCONINO CO
GILA CO
TONTO
NATIONAL
FOREST
Myrtle Lake
Myrtle Point
Horseshoe Lake
Beaver Park
PROMONTORY BUTTE
Bear Canyon Lake
Roberts Mesa
TONTO CREEK
INDIAN GARDENS
Thompson

Figure 23

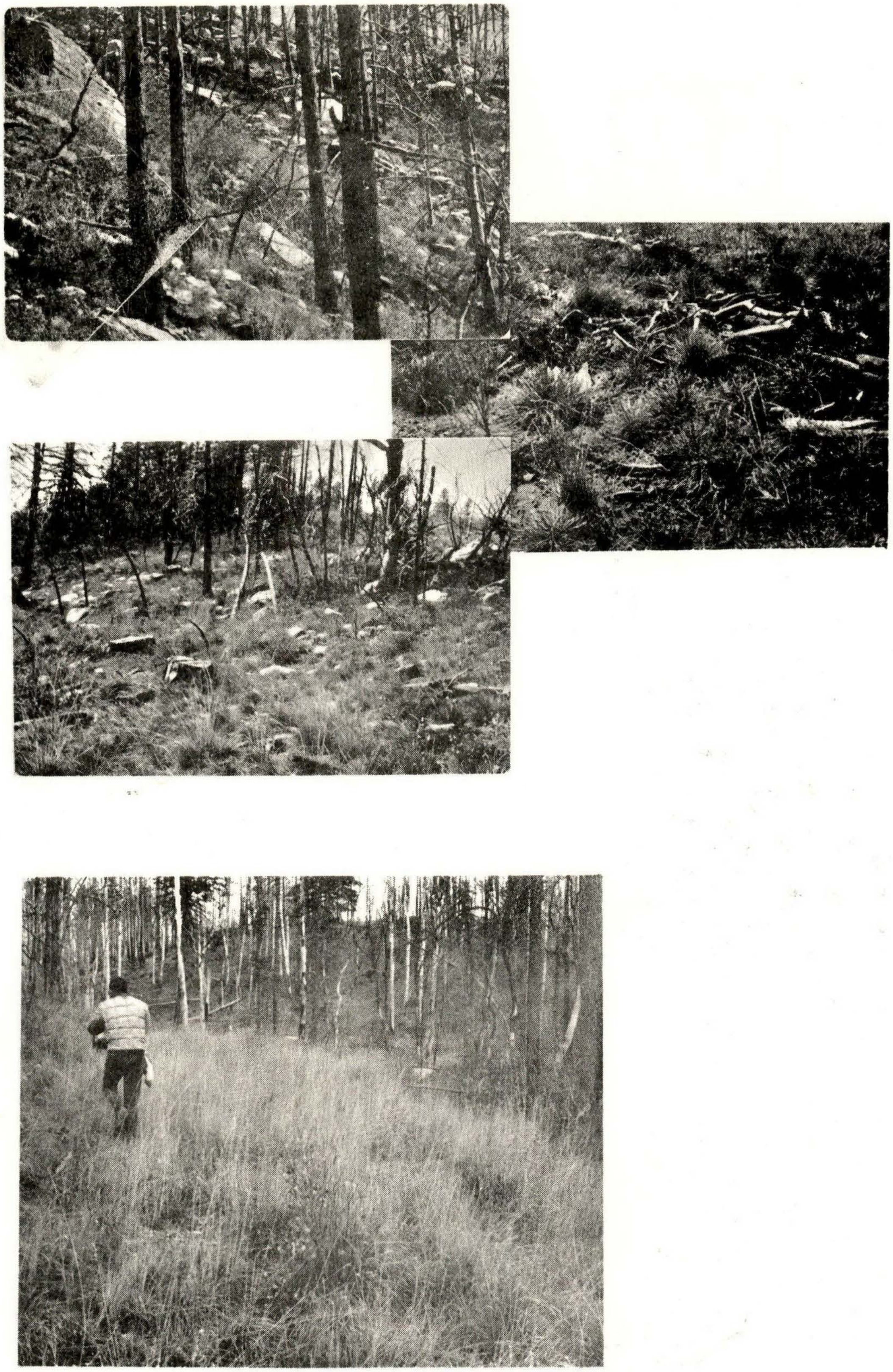


Photo 19 - Seeded grasses on upper slopes of 1968 Hatchery Burn provide good ground cover protection.

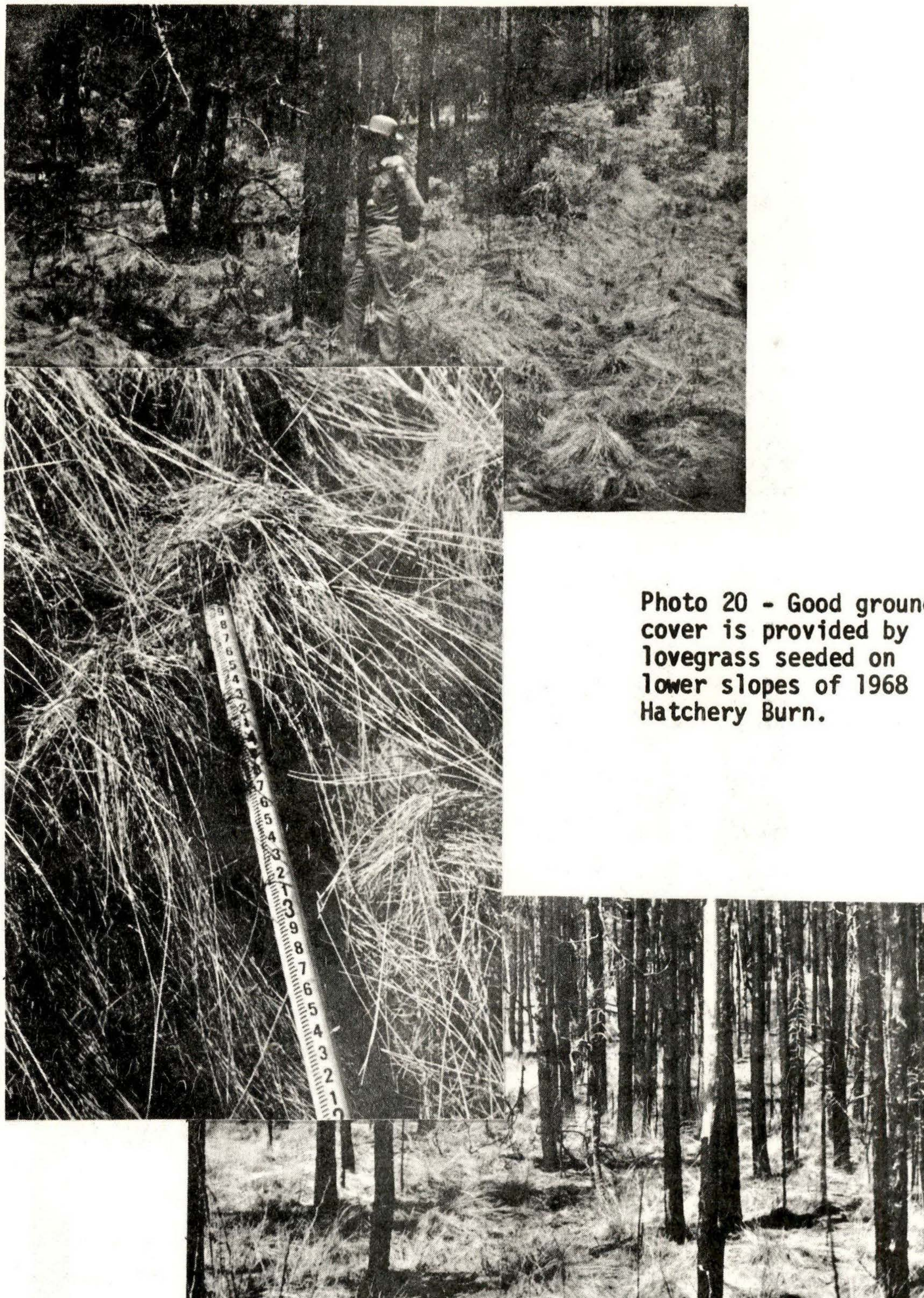


Photo 20 - Good ground cover is provided by lovegrass seeded on lower slopes of 1968 Hatchery Burn.

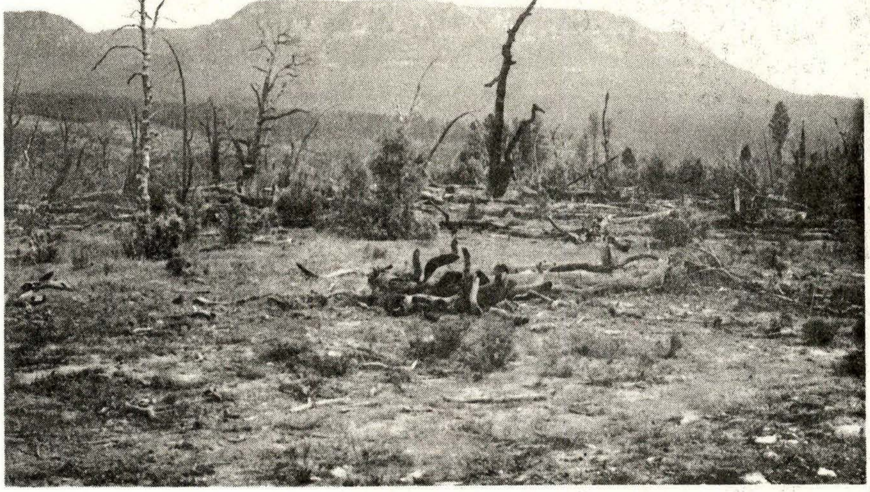


Photo 21 - The Roberts Burn with its soils of low infiltration capacity and sparse ground cover was a high storm runoff producing area. However, its moderate slopes and low channel gradients prevented this area from developing severe channel damage.

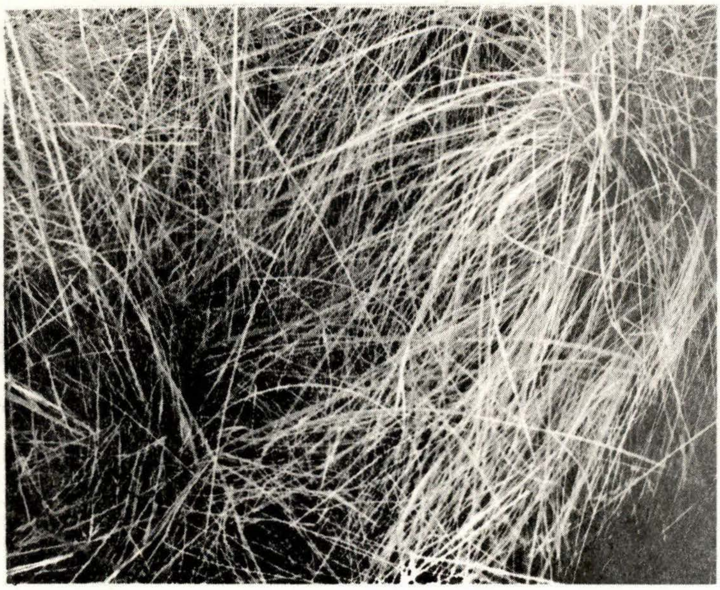


Photo 22 - Seeded lovegrass in powerline right-of-way demonstrates the ability of seeded grasses to provid excellent ground cover protection.

The Indian Garden Grazing Allotment and the Tonto Creek Watershed nearly coincide. All of the watershed below the rim is within the allotment and only 2,500 acres of the allotment lies outside the watershed boundary. The annual grazing permits since 1958 have provided for around 60 head of cattle yearlong and for yearling cattle ranging from none to 45 head for the period January 1 to October 31. Prior to the Roberts Fire in 1961, the permitted cattle depended heavily on browse due to the scarcity of palatable grasses. Since the fire, the revegetated burn has provided an island of forage and as such has received heavy use. Improvements consist of corrals, a house on patented land, a holding pasture, and a corral in the vicinity of Indian Gardens. Stock water is provided from the open perennial streams.

Through intensified livestock management and control, the potential for overland flow could be reduced from the Roberts Burn. This area at the time of the survey had 40 percent ground cover protection where the potential is estimated at 70 percent. The decrease in overland flow would not be great due to the inherent low infiltration rates of the soil, but it would be beneficial. For example, it is estimated that the Roberts Burn, with its maximum potential grass cover of 70 percent would have reduced the amount of overland flow from this burned area in the September 1970 flood by 0.44 area inches or four percent. During the critical runoff period, the reduction in runoff would have been 0.16 area inches or 10 percent. As the amount of rainfall decreases for any one storm, the benefits of increased ground cover would increase. However, the greatest benefit from decreasing runoff would be more infiltrated rainfall which would increase forage production and reduce sheet erosion.

The Phoenix-Four Corners 345 KV power transmission line corridor crosses the watershed in a northeasterly southwesterly direction. The permit for this line included 26 supplemental requirements to insure soil stabilization and water quality protection. Revegetation with lovegrasses was highly successful and soils within the right-of-way are well stabilized as shown in photo 22.

33. *As a result of natural scouring during the flood and a $400,000 emergency channel restoration program by the Forest Service on National Forest lands complimented by a similar program by the Corps of Engineers on private lands, the major stream channels in the Tonto Creek Watershed have more capacity to carry flood waters today than they had prior to September 5, 1970.*

From the preceding documentations, it can be seen that the Labor Day Flood greatly disrupted and damaged National Forest land and improvements in this watershed. The first major effort to restore this watershed to favorable hydrologic conditions is now complete. Project Ringtail

was the code name of an emergency rehabiliation project in which $400,000 were expended on National Forest land in clearing debris from channels to alleviate flood threats under the Mogollon Rim. A similar program was carried out on private lands by the Corps of Engineers. As a result of the flood's scouring and these rehabilitation programs, the major stream channels in the Tonto Creek Watershed have more capacity to carry flood waters today than they had prior to September 5, 1970.

Insect damage potential is examined periodically. If remedial measures are needed to suppress an insect infestation as a result of the flood, recommendations will be made for control.

Much work remains to be done in the repair and replacement of damaged and destroyed improvements. Many years, careful planning, and a large expenditure of funds will be required to complete man's responsibilities. Nature has begun its job of restoration also, as first evidenced by the appearance of small aquatic plants and animals. How long it will be before nature again reverses itself and makes a catastrophic adjustment in shaping and molding the earth's surface in the vicinity of Tonto Creek cannot be predicted.

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